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NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

TECHNICAL REPORT

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DETERMINATION OF HEAD AND NECK LOADS AND MOMENTS DURING TACTICAL AND ROTARY WING MANEUVERING ACCELERATION

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14. ABSTRACT Neck injury risk can increase when aircrew wear head mounted equipment while exposed to +Gz loads. The effects of added weight and change in center of gravity (CG) were determined during a centrifuge study using an instrumented manikin at Brooks Air Force Base, Texas. Data included centrifuge Gz, head acceleration (three axes), head and C7-T1 pitch moment, and compressive and shear forces. Helicopter (0.5 G/sec at +1.75 and +4 Gz) and tactical aircraft (2 and 6 G/sec from +4 to 12 Gz) accelerations were simulated (5 sec plateau at each level). Effect of added weights (up to overall 2.7 kg) was measured in the forward pitch and lateral planes and tested using ANOVA. Seven real helmet systems were also tested. Head Gx and Gy increased with increasing +Gz load, head weight, as CG shifted in the forward pitch plane, and onset rate. Head Gz was greatest when weight was distributed laterally. The resultant head and neck force and moment increased with increasing weight, pitch angle, and +Gz load. Neck forces and moments were significantly larger than those measured in the head.					
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SUMMARY

This study was conducted to support the NAVAIR "Human Tolerance To Acceleration Induced Spinal Injury Program." The intent of this program is to characterize the risks and identify the tolerance of the neck to injury of both fixed and rotary wing aircrews. The ultimate product of this program will be a set of safety design criteria for programs involving head-borne equipment that accommodates risks during maneuvering and impact acceleration. Prior to developing injury criteria, it is necessary to describe the domain of acceleration forces and moments in the head and neck during G-forces associated with rotary and tactical maneuvering flight. This report describes the effects of added head weight, the distribution of that weight, and the onset acceleration rate on these parameters.

The effects of added weight and change in center of gravity (CG) were determined during a centrifuge study using an instrumented manikin at Brooks Air Force Base, Texas. A unique test fixture was developed which attached to the manikin's head and provided a support structure for adding head-borne weight and changing the CG. Data included centrifuge Gz, head acceleration (three axes), head and C7-T1 pitch moment, and compressive and shear forces. Acceleration vectors, with respect to the head, are defined as forward (+Gx), rightward (+Gy), and downward (+Gz). Helicopter (0.5 G/sec at +1.75 and +4 Gz) and tactical aircraft (2 and 6 G/sec from +4 to 12 Gz) accelerations were simulated (5 sec plateau at each level). Effect of added weights (up to overall 6 lb) was measured in the forward pitch and lateral planes and tested using ANOVA. Seven real helmet systems were also tested. Head Gx and Gy increased with increasing +Gz load, head weight, as CG shifted in the forward pitch plane, and onset rate. Head Gz was greatest when weight was distributed laterally. The resultant head and neck force and moment increased with increasing weight, pitch angle, and +Gz load. Neck forces and moments were significantly larger than those measured in the head.

Contents

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- Phillip Whitley, Ph.D., for his original design of the Shogun fixture and for his encouragement.

INTRODUCTION

BACKGROUND

1. The cervical muscles and vertebrae of aircrew in high performance aircraft are repeatedly exposed to G levels and high-G onset rates during aerial combat and air-to-ground maneuvers. Under these conditions, injury can occur ranging in severity from muscle strain to vertebral fracture. Several studies have been conducted to quantify the incidence of neck injury in U.S. Navy (USN), U.S. Air Force (USAF), and European Air Forces aircrew (references 1 through 6). For example, a 1988 survey of 66 F/A-18 pilots indicated 79% experienced neck pain; in 56%, the pain interfered with present and future missions and 17% were removed from flight status (reference 7). Although advanced materials have been developed which decrease helmet weight, the helmet is now used as a platform for mounting avionics. These devices add weight and may pitch the center of gravity (CG) forward, thereby increasing the risk of injury. The result is diminished aircrew performance and reduced operational readiness.

2. The U.S. Naval Air Systems Team "Human Tolerance To Acceleration Induced Spinal Injury Program" was developed to characterize the risks and identify the tolerance of the neck to injury of both fixed and rotary wing aircrews. The objective of this project is to develop a set of design criteria for programs involving head-borne equipment that predicts risks during maneuvering and impact acceleration. The core of this project involves anatomical modeling of the cervical spine. Prior to developing injury criteria, it is necessary to describe the domain of acceleration forces and moments in the head and neck during G-forces associated with rotary and tactical maneuvering flight. This report describes the effects of added head weight, the distribution of that weight, and the onset acceleration rate on these parameters.

PURPOSE

3. The purpose of this study was to characterize the effects of added weight and change in CG on head acceleration and head and neck loads and moments during conditions simulating tactical and helicopter maneuvering flight.

METHOD

TEST ARTICLES AND TEST SITE

4. The tests were conducted at the Brooks Air Force Base centrifuge in San Antonio, Texas. The centrifuge has a 20 ft arm length, a +30 Gz maximum capability, and a 6 G/sec maximum onset rate.

5. The test manikin was an instrumented "aerospace" Hybrid III 50th percentile male with a Hybrid II head (9.48 lb) and custom-made solid aluminum neck. The latter was used instead of a Hybrid III neck since a previous study found that unrealistic hyperflexion and rebound occurred when exposed to maneuvering +Gz loads. A custom-made aluminum fixture, similar in shape to a Japanese "Shogun" helmet, was fabricated which fastened directly to the manikin's head via

the back skull plate. The fixture provided mounting locations for adding weight in the frontal and sagittal planes (figure 1). Test configurations involved placing weights at strategic locations around the fixture in the forward pitch plane and laterally (table 1). For a given +Gz level, effects on head/neck loads of adding additional weight in the forward pitch plane in 0.5 lb increments from 4-5.5 lb (tactical) and from 4-6 lb (helicopter) were determined. Weight ranged from 4-6 lb in 0.5 lb increments (4-6 lb) for lateral conditions. The effects of asymmetric lateral loads were also tested at 4.5 and 5.5 lb. The control configuration, which simulated the weight of a standard tactical helmet and oxygen mask (3.5 lb), consisted of the 2 lb Shogun fixture with 0.75 lb added at lateral positions 6L and 6R. In addition, USN, USAF, and U.S. Army helmet systems were also tested (table 1). For each weight and position combination, overall weight (including the headform and neck), CG (relative to the occipital condyles), and mass moments of inertia were determined using a KGR-30 Mass Properties Measurement System (Space Electronics, Incorporated, Meridian, Connecticut).

6. The manikin was held in the centrifuge ejection seat using an integrated lap belt and shoulder straps. Ratchet tiedowns (1,300 lb rated capacity) were placed under the manikin's armpits to secure its torso, across the hips to secure the pelvis, and a third secured the hands and upper thighs to the seat to minimize shifting under +Gz load. The manikin's feet were restrained to the footrest with belt webbing.

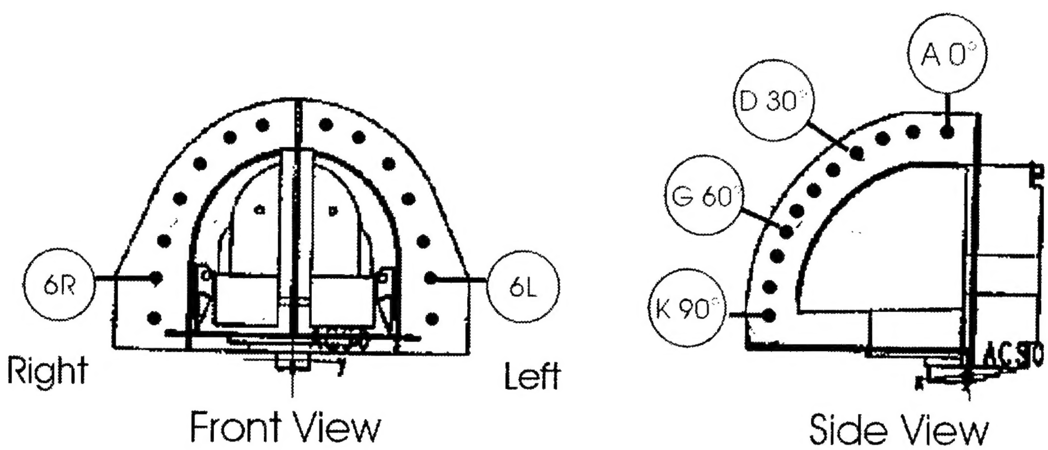


Figure 1: "Shogun" Test Fixture

Table 1: Shogun Fixture Weight Configuration and Real Helmet Systems Tested
(All Configurations Except the Actual Systems Had 0.75 lb in 6L and 6R Positions)

Head-Supported Mass Configurations and Helmet Systems Tested	
Shogun Test Series	
Weight Configuration	Hole Locations
Control	
Lateral	6L, 6R
Right Asymmetric Lateral	6L, 6R (0.5 or 1 lb), K (0.5 lb)
Left Asymmetric Lateral	6L (0.5 or 1 lb), 6R, K (0.5 lb)
0 deg Pitch	A
30 deg Pitch	D
60 deg Pitch	G
90 deg Pitch	K
Real Helmet Systems (Without Masks) Test Series	
USN HGU-84/P Helicopter (NH)	
USN HGU-84/P Helicopter with ANVIS Night Vision Mockup (NHV)	
U.S. Army HGU-56/P Helicopter (AH)	
USN HGU-68/P Tactical (NT)	
USAF HGU-55/P Lightweight Tactical (AFT)	
USN Crusader Prototype Tactical Day/Night (NDN)	
USN/USAF Joint Helmet Mounted Cueing System (JHMCS)	

ACCELERATION PROFILES

7. Three types of acceleration profiles were used to simulate +Gz stress (i.e., the reaction to applied +Gz force) associated with rotary and tactical missions (figure 2). Helicopter +Gz forces were based on in-flight measurements (reference 8), including a 0.5 G/sec onset to a moderate (+1.75 Gz) and high (+4 Gz) 5 sec plateau. Tactical 5 sec plateaus were +4, 6, 8, 10, and 12 Gz at rapid (2 G/sec) and very high (6 G/sec) onset rates. In addition, the effects of 90 sec simulated aerial combat maneuvering (SACM) were determined using two Gillingham SACM's (reference 9) featuring +6 and +10 Gz peak loads. Peak accelerations, moments, and forces were calculated (mean ± one standard deviation) during the last 2 sec at each plateau.

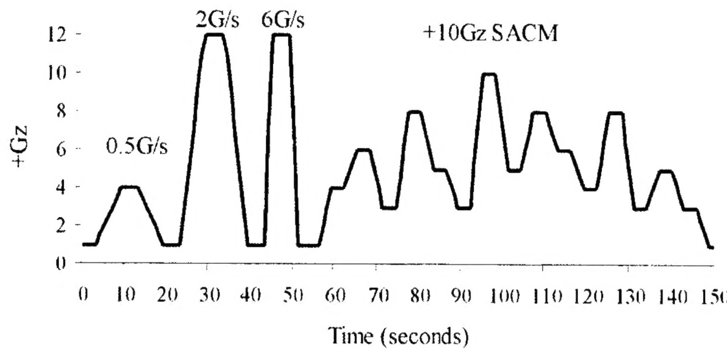


Figure 2: Sample Centrifuge +Gz Profiles for Helicopter (0.5 G/sec), Rapid (2 G/sec), and Very High (6 G/sec) Onset Tactical Profiles and +10 Gz Peak Gillingham SACM

MEASUREMENTS AND DATA ANALYSIS

8. Eleven channels of data were collected at 100 Hz, including centrifuge Gz, head acceleration (three axes 25 G Endevco Model 7264A, where +Gy is rightward, +Gx is forward, +Gz is down), head and C7-T1 pitch moment (My), compressive (Fz) and shear (Fx and Fy[1]) forces, and forward displacement of the head (Patriot linear motion transducer Model P-25B either attached to Shogun position 5R or to a similar stop on the real helmet systems). Load cells included a Denton Model 1716 (head) and a Denton Model 1914 (neck). Two video cameras recorded frontal and side motion. Phototargets were added to the manikin's head and to fixed reference points in the centrifuge cab.

9. ANOVA with Fisher's Least Squares Difference post-hoc tests were first conducted to determine the effects of weight, weight position, +Gz load, and onset rate. For every configuration, +Gz load was typically an overwhelming factor leading to statistical significance, which could have masked the contribution of other factors. Therefore, tests were run at each given +Gz load to determine the effects of the other factors. Tests were run with a complete model and then rerun with nonsignificant factors removed. Paired t-tests were conducted to determine if there was a significant difference between head and neck moments and forces. Significance was set at $p = 0.05$.

10. To determine the effects of added weight and its distribution during SACM, ANOVA were run comparing values obtained during the 5 sec plateaus with the corresponding +Gz loads during the SACM. Factors included weight, weight position, and type (plateau or SACM) at +4, 6, 8, and 10 Gz for the +10 Gz SACM. A separate test was conducted for repeated +Gz loads during the SACM (+4 and +6 Gz repeated twice, +8 Gz three times) to determine if values measured later during the SACM were different from the first exposure.

11. The effect of asymmetric loads was determined by comparing those configurations to the closest symmetric configuration, 4 lb at 90 deg pitch.

[1] During asymmetric lateral loads, after Fz and Fx were measured, exposures were repeated without Fx to measure Fy since additional amplifiers were not available.

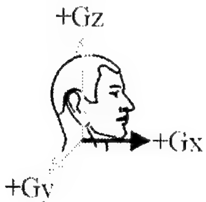
RESULTS

12. Overall, the test program comprised 462 runs, representing 35 different head weight configurations (30 Shogun configurations and 7 actual helmet systems). Weight and CG data are given in table 2.

Table 2: Weight and CG Relative to the Occipital Condyles, Including the Headform, for Test Configurations

Summary of Weight (lb) and CG (in.) of Head Support Mass					
			CG		
Configuration	Added Weight	Total Weight	X	Y	Z
Headform	-	9.5	-0.100	-0.022	-0.004
Shogun	0.0	11.5	0.108	0.006	0.003
Control	1.5	13.0	0.001	0.023	0.152
Lateral	1.0	13.5	-0.029	0.028	0.194
	1.5	14.0	-0.054	0.032	0.229
	2.0	14.5	-0.083	0.037	0.270
	2.5	15.0	-0.107	0.041	0.302
	3.0	15.5	-0.130	0.045	0.335
0.5 lb Right Asymmetric	0.5 (90 deg) and 0.5 (6R)	14.0	0.240	0.182	0.244
1.5 lb Right Asymmetric	0.5 (90 deg) and 1.5 (6R)	15.0	0.174	0.480	0.311
0.5 lb Left Asymmetric	0.5 (90 deg) and 0.5 (6L)	14.0	0.236	-0.140	0.247
1.5 lb Left Asymmetric	0.5 (90 deg) and 1.5 (6L)	15.0	0.163	-0.420	0.320
90 deg Pitch	0.5	13.5	0.028	0.028	0.428
	1.0	14.0	0.052	0.033	0.684
	1.5	14.5	0.075	0.038	0.922
	2.0	15.0	0.096	0.042	1.145
	2.5	15.5	0.116	0.046	1.353
60 deg Pitch	0.5	13.5	0.144	0.024	0.414
	1.0	14.0	0.277	0.024	0.657
	1.5	14.5	0.400	0.025	0.883
	2.0	15.0	0.515	0.026	1.094
	2.5	15.5	0.623	0.026	1.292
30 deg Pitch	0.5	13.5	0.238	0.018	0.334
	1.0	14.0	0.457	0.014	0.504
	1.5	14.5	0.662	0.009	0.662
	2.0	15.0	0.853	0.005	0.809
	2.5	15.5	1.031	0.002	0.947
0 deg Pitch	0.5	13.5	0.277	0.016	0.207
	1.1	14.0	0.534	0.009	0.258
	1.5	14.5	0.773	0.003	0.305
	2.0	15.0	0.995	-0.003	0.350
	2.5	15.5	1.204	-0.008	0.391
	Helmet Weight				
JHMCS	4.0	13.5	0.259	-0.020	2.589
NDN	5.4	14.9	0.326	0.011	2.306
NT	3.0	12.5	0.099	0.032	1.939
AFT	3.3	12.8	0.107	0.008	1.958
NH	3.2	12.7	-0.081	0.045	2.245
NHV	5.1	14.6	0.229	0.017	2.446
AH	2.8	12.3	-0.098	0.083	2.044

HEAD ACCELERATION



HEAD Gx

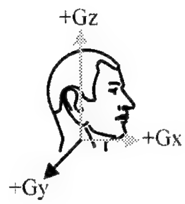
13. For the tactical simulations, Head Gx (HGx) increased as +Gz load and weight rose, ranging from +4 Gz control levels of 0.24 G (2 G/sec) and 0.26 G (6 G/sec) to 5.5 lb 60 deg pitch values of 2.94 G (2 G/sec) and 2.97 G (6 G/sec) at +12 Gz (tables B-1 and B-2). HGx was greater at 6 G/sec onset rate than 2 G/sec for tactical simulations at +4 through +10 Gz ($F > 83.4$, $p < 0.001$). During tactical runs, HGx was greatest at the 60 deg pitch with 4.5, 5, and 5.5 lb. At 4 lb, HGx was greatest at the 30 deg pitch during +4 Gz (2 and 6 G/sec) and during 6 and 8 Gz at 6 G/sec. The results indicated that at each tactical +Gz level, HGx was significantly different for each tested weight ($F > 526.5$, $p < 0.001$). For example, when compared with the 3.5 lb control at 2 G/sec for all +Gz loads, HGx increased by 53 ± 4% (4 lb), 75 ± 1% (4.5 lb), 96 ± 6% (5 lb), and 116 ± 12% (5.5 lb). For the actual tactical helmet systems, while HGx rose with increasing +Gz load, there were no differences based on onset rate. HGx with JHMCS was significantly greater than the other three tactical systems for each +Gz load ($F > 8.36$, $p < 0.033$). HGx with NDN was significantly lower than with AFT and JHMCS at +8, 10, and 12 Gz ($F > 62.78$, $p < 0.001$) and lower than NT at +10 and 12 Gz ($F > 235.0$, $p < 0.001$).

14. For helicopter simulations (table B-22), HGx with 6 lb weight was significantly greater than the lighter weights ($F > 8.6$, $p \leq 0.003$) and HGx with the lateral configuration was significantly lower than the forward pitch positions ($F > 11.2$, $p < 0.001$). HGx ranged from control values of 0.04 and 0.24 G (+1.75 and 4 Gz, respectively) to 6 lb levels of 0.16 and 0.60 G (+1.75 and 4 Gz, respectively). Similar to the tactical runs, HGx was greatest at 60 deg pitch with 4.5, 5, and 6 lb and at 30 deg pitch with 4 lb. There were no statistically significant differences in HGx between the three helmet systems.

15. Results of comparing the effects of asymmetric loads with the 4 lb 90 deg pitch configuration indicated that HGx for both the 0.5 and 1.5 lb asymmetric configurations were greater during +4 Gz ($F = 9.3$, $p = 0.01$) and +6 Gz ($F = 5.0$, $p = 0.04$) levels at both 2 and 6 G/sec onset rates. There were no statistical differences at the helicopter onset rate (0.5 G/sec).

16. When comparing data during the 5 sec plateau exposures to equivalent +Gz loads during the +10 Gz SACM, SACM HGx were greater. The results of an ANOVA comparing all weights and orientations indicated that the difference was significant for the +4, 6, 8, and 10 Gz levels ($F > 20.1$, $p < 0.001$). On average, +10 Gz SACM HGx were 16.4 ± 1.9% (+4 Gz), 14.1 ± 1.2% (+6 Gz), 8.9 ± 1.2% (+8 Gz), and 3.6 ± 0.6% (+10 Gz) greater than comparable 5 sec plateau levels. Furthermore, during the SACM, HGx was significantly greater during the second as compared to the first peak and there was a statistical interaction between the run number and

weight position for +4 Gz (21.1 ± 0.4% greater; $F = 46.2$, $p < 0.001$), +6 Gz (15.4 ± 1.2% greater; $F = 17.7$, $p < 0.001$), and +8 Gz (5.6 ± 0.5% greater; $F = 14.1$, $p < 0.001$) loads. Summary HGx SACM data are found in table B-3.

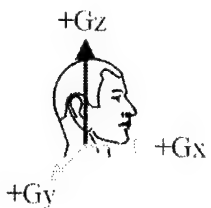


HEAD Gy

17. Head Gy (HGy) was directed leftwards (-Gy) and also increased with rising +Gz load, head weight, and onset rate, ranging from +4 Gz control configuration levels of –0.21 G (2 G/sec) and –0.27 G (6 G/sec) to –1.03 G (0 deg pitch, 2 G/sec) and –1.04 G (30 deg pitch, 6 G/sec) with 5.5 lb at +12 Gz (tables B-4 and B-5). When compared to the 3.5 lb control at 2 G/sec for all +Gz loads, HGy was 60 ± 15% (4 and 4.5 lb) and 65 ± 15% (5 and 5.5 lb) greater and, at 6 G/sec, the increase was 39 ± 6% (4 and 4.5 lb) and 41 ± 5% (5 and 5.5 lb). ANOVA results indicated that HGy was statistically greater at 6 G/sec compared with 2 G/sec for tactical simulations at +4 through +10 Gz ($F > 17.5$, $p < 0.001$), although the differential magnitude was low. For the lateral weight configuration tests, HGy were significantly smaller than the forward pitch positions for all +Gz loads. The highest HGy were recorded for the 0 deg pitch configuration during +4 to 10 Gz (30 deg pitch HGy were slightly greater at +12 Gz) ($F > 17.4$, $p < 0.001$). As the weight pitched further forward towards 90 deg, HGy progressively diminished. To summarize the effects of overall weight, HGy with the 4 lb weight was significantly less than the other weights at all +Gz loads ($F \geq 3.5$, $p \leq 0.028$), with the exception that HGy with both 4 and 4.5 lb at +4 Gz were equivalent. In addition, HGy with the 4.5 lb were significantly less than the 5 and 5.5 lb at +8, 10, and 12 Gz ($F \geq 22.3$, $p < 0.001$). At +10 Gz, HGy between the 5 and 5.5 lb were also statistically different ($F = 67.7$, $p < 0.001$). For the actual tactical helmet systems, HGy rose with increasing +Gz load and HGy was statistically significantly greater at 6 G/sec than 2 G/sec during +4, 10, and 12 Gz loads ($F > 10.2$, $p < 0.05$). There were significant differences in HGy between the actual systems at +4 ($F = 17.1$, $p = 0.021$), 10 ($F = 22.1$, $p = 0.015$), and 12 ($F = 40.0$, $p = 0.006$) Gz: JHMCS less than NDN and NT; NDN greater than NT at +12 Gz; NDN greater than AFT (+4, 10, and 12 Gz), and NT greater than AFT at +10 and 12 Gz.

18. For the helicopter simulations (table B-22), +Gz load had a significant effect on HGy ($p < 0.001$) but overall weight did not. HGy at 0 and 30 deg pitch were greater than at lateral and 90 deg pitch configurations during +1.75 ($F = 5.7$, $p = 0.005$) and 4 ($F = 4.5$, $p = 0.014$) Gz. HGy at 0 deg pitch was also greater than 60 deg pitch during +1.75 Gz. Note that HGy magnitude was quite modest even though the relative difference between the control and 5.5 lb 30 deg pitch was high (45%): +1.75 Gz: -0.11 G (control) versus –0.20 G (5.5 lb) and –0.20 G (control) versus -0.37 G (5.5 lb). There were no statistically significant differences in HGy between the three helmet systems.

19. There were no significant differences in HGy between the asymmetric loads and the 4 lb 90 deg pitch configuration for helicopter and tactical onset rates. An ANOVA of the HGy during the +10 Gz SACM comparing all weights and orientations indicated that HGy was greater during the SACM as compared to equivalent 5 sec plateau values at +4, 6, 8, and 10 Gz levels ($F > 36.0$, $p < 0.001$). Mean +10 Gz SACM HGy were 16.5 ± 1.9% (+4 Gz), 16.2 ± 2.2% (+6 Gz), 11.7 ± 1.8% (+8 Gz), and 5.7 ± 1.0% (+10 Gz) greater than comparable 5 sec plateau levels (table B-6). As with HGx, HGy was significantly greater during the second peak as compared to the first during the SACM ($F > 1290$, $p < 0.001$), averaging 22.3 ± 0.8% (+4 Gz), 13.7 ± 0.4 (+6 Gz), and 7.5 ± 0.3% (+8 Gz).



HEAD Gz

20. Head Gz (HGz) significantly increased with +Gz load ($p < 0.001$). ANOVA results indicated that HGz varied with weight ($F > 21.0$, $p < 0.001$), weight position ($F > 54.4$, $p < 0.001$), and that there was a statistical interaction between weight and its position ($F > 6.3$, $p < 0.001$) (tables B-7 and B-8). HGz ranged from 92.8 to 95.5% of the applied +Gz stress. HGz was greatest when the weight was distributed laterally and was the least at the 60 deg pitch position. Post-hoc analysis indicated that HGz with weight distributed in these two positions were different from all other positions at all +Gz loads. HGz at 0 deg pitch was also statistically significantly different from lateral, 60 deg, and 90 deg pitch values. HGz was significantly less with the 5.5 lb configuration than lower weights for each +Gz load ($F > 21.0$, $p < 0.001$). HGz for the 5 lb configuration was also associated with lower levels as compared to the 4.5 and 4 lb weights for +6 to +12 Gz (at +4 Gz, HGz at 5 lb was less than the 4.5 lb only). While these statistical results indicate significant differences, the magnitude of the differences is quite small, ranging from 0.08 G (+4 Gz), 0.12 G (+6 Gz), 0.18 G (+8 Gz), 0.27 G (+10 Gz), to 0.35 G (+12 Gz). Similarly, even though HGz during the 2 G/sec runs were statistically greater than during 6 G/sec runs ($F > 4.4$, $p < 0.049$), differences were on the order of 0.01 G. For the actual helmet systems, HGz measured with JHMCS was less ($p < 0.001$) than the other helmet systems at +10 Gz (by 0.07 ± 0.01 G) and +12 Gz (by 0.11 ± 0.01 G).

21. For helicopter simulations (table B-22), HGz with 6 lb was significantly less than 4 and 4.5 lb during +4 Gz ($F = 5.3$, $p = 0.015$), whereas at +1.75 Gz, weight had no effect on HGz. HGz for lateral loads were significantly greater than the pitch positions for both +1.75 ($F = 5.2$, $p = 0.008$) and +4 Gz ($F = 8.2$, $p = 0.002$) loads. HGz was lowest with weight in the 60 deg pitch position but, as with the tactical simulations, the differences were very small (+1.75 Gz: 0.02 ± 0.01 G; +4 Gz: 0.04 ± 0.01 G). There were no statistically significant differences in HGz between the three helmet systems.

22. HGz for the 4 lb 90 deg pitch configuration were larger than both the 0.5 and 1.5 lb asymmetric configurations for tactical +4 through +10 Gz loads (only 0.5 lb at +12 Gz) ($F > 6.5$, $p < 0.032$). HGz was greater during the 2 G/sec runs as compared to the 6 G/sec for +4 ($F = 11.4$, $p < 0.015$) and +8 Gz ($F = 10.7$, $p < 0.017$) loads. There were no differences at 0.5 G/sec.

23. Results of the ANOVA of the +10 Gz SACM runs indicated that HGz during the SACM were greater for the +4 and +6 Gz levels ($F > 30.9$, $p < 0.001$) and, for the +10 Gz, the 5 sec plateau levels were greater ($F = 24.8$, $p < 0.001$). Unlike HGx and HGy, HGz was greater (0.01 to 0.03 G) during the first peak as compared to the second for +4, +6, and +8 Gz loads ($F > 83.9$, $p < 0.001$) (table B-9). There was also a statistical interaction between the weight position and run number for +4, +6, and +8 Gz loads ($F > 4.1$, $p < 0.003$). This confirmed that the highest HGz for the +10 Gz SACM occurred during the first peak with lateral and 0 deg pitch weight positions.

HEAD LOADS

24. The resultant head load from the compressive (head Fz) and forward shear (head Fx) forces were calculated (HFxz) for symmetric weight configurations. For asymmetric runs, the resultant head Fz and total shear (Fx and Fy) forces were calculated (HFxyz) (tables B-10 and B-11). Compared to the control configuration, the maximum relative change in HFxz with each 0.5 lb increase in overall weight was consistent at each +Gz load (4 lb: $8 \pm 1\%$; 4.5 lb: $16 \pm 3\%$; 5 lb: $22 \pm 4\%$; 5.5 lb: $28 \pm 6\%$). HFxz increased as weight, +Gz load, and onset rate increased. HFxz rose with increasing pitch angle, with the lowest forces associated with the lateral configuration and the maximum at the 60 deg pitch configuration. Post-hoc analysis indicated that HFxz at every configuration were significantly different from each other ($F > 617$, $p < 0.001$) at every +Gz load. HFxz at each overall weight were different from each other at every +Gz load as well ($F > 3180$, $p < 0.001$). There was a statistical interaction between pitch angle and weight at each +Gz load ($F > 28.1$, $p < 0.001$), which confirmed that the lowest forces were measured with 4 lb configured either laterally or at 0 deg pitch and the greatest forces with 5.5 lb configured at 60 deg or 90 deg pitch. While there was a significant statistical difference between HFxz measured at 2 and 6 G/sec for every +Gz load ($F > 18.5$, $p < 0.001$), the differential magnitude was small (<1%). HFxz measured for the actual tactical helmet systems were statistically significantly different from each other at each +Gz load tested, with NDN > JHMCS > NT > AFT ($F > 164.0$, $p < 0.001$).

25. For the helicopter simulations (table B-23), HFxz significantly increased with heavier weights at both +1.75 ($F = 57.9$, $p < 0.001$) and +4 Gz ($F = 121.2$, $p < 0.001$). During +1.75 Gz runs, HFxz with the lateral configuration was significantly less than all other pitches ($F = 9.0$, $p = 0.001$), whereas there were no differences in HFxz between the pitches themselves. At +4 Gz, HFxz measured at the lateral and 0 deg pitch were significantly lower than the other configurations ($F = 13.2$, $p < 0.001$). There were no statistically significant differences in HFxz between the three helmet systems.

26. HFxz for the 4 lb 90 deg pitch configuration were statistically significantly less than both the 0.5 and 1.5 lb asymmetric configurations for all tactical Gz loads ($F > 9.0$, $p < 0.012$). Post-hoc analysis indicated a significant difference between the 0.5 and 1.5 lb asymmetric configurations at each +Gz load except +4 Gz. HFxz was greater during the 6 G/sec onset rate as compared to the 2 G/sec for asymmetric configuration at +6 Gz only ($F = 11.9$, $p = 0.014$). There were no differences at 0.5 G/sec.

27. Results from the +10 Gz SACM runs indicated that HFxz during the SACM were significantly greater at +4, +6, +8, and +10 Gz levels than the corresponding 5 sec plateau levels ($F > 21.8$, $p < 0.001$). HFxz was statistically less (approximately 1 lb) during the first peak as compared to the second for +4, +6, and +8 Gz levels ($F > 73.6$, $p < 0.001$) (table B-12). There was also a statistical interaction between the weight position and run number for +4 and +8 Gz loads ($F > 3.6$, $p < 0.005$). This indicated that the higher HFxz during the +10 Gz SACM occurred during the second peak with 60 deg pitch weight positions at these +Gz plateaus.

NECK LOADS

28. The resultant neck loads (NFxz) were calculated in a similar fashion as the head for compressive (NFz) and forward shear (NFx) forces for symmetric weight configurations and asymmetric runs (NFxyz) (tables B-13 and B-14). In a similar fashion to HFxz, when compared to the control configuration, the maximum relative change in NFxz with each 0.5 lb increase in overall weight was again consistent at each +Gz load (4 lb: 6 ± 2%; 4.5 lb: 9 ± 2%; 5 lb: 12 ± 3%; 5.5 lb: 15 ± 4%). NFxz rose as weight ($F > 3209$, $p < 0.001$) and +Gz load increased for all +Gz loads. There were significant differences in NFxz depending upon weight position ($F > 49.8$, $p < 0.001$). The weights in the lateral configuration were associated with the lowest NFxz for all +Gz loads. There was also a statistical interaction between weight and position at every +Gz load ($F > 6.8$, $p < 0.001$). The post-hoc analysis of the interaction indicated that, as the +Gz level increased, the highest measured NFxz varied with both pitch angles and weights. At +4 Gz, the greatest NFxz occurred at 30 deg pitch at 4 lb but switched to 0 deg pitch at 4.5 to 5.5 lb. There was a 13% difference in NFxz at +4 Gz between 4 lb lateral and 5.5 lb 0 deg pitch. At +6 Gz, the highest NFxz were measured at 30 and 90 deg pitch for 4 lb, 90 and 0 deg pitch for 4.5 lb, 0 and 60 deg pitch for 5 and 5.5 lb. There was an overall 10% difference in NFxz at +6 Gz between 4 lb lateral and 5.5 lb 0 deg pitch. At +8 Gz, the peak NFxz were recorded at 30 and 90 deg pitch for 4 lb, 90 deg pitch for 4.5 lb, 60 and 0 deg pitch for 5 lb, and at 60, 30, and 90 deg pitch for 5.5 lb. At +8 Gz, there was an overall difference of 9% between the 4 lb lateral and 5.5 lb 60 deg pitch. The highest NFxz measured during +10 Gz plateaus occurred with 4 lb at 90 and 30 deg pitch, 4.5 lb at 90 deg pitch, 5 lb at 60, 0, and 90 deg pitch, and for 5.5 lb, there were no differences between the forward pitch angles. There was an overall increase of 8% at +10 Gz between the 4 lb lateral and 5.5 lb 0 deg pitch. During +12 Gz, the greatest NFxz occurred with 4 and 4.5 lb at 90 deg pitch and, at 5 and 5.5 lb, there were no differences between the forward pitch angles. For +12 Gz runs, there was an overall difference of 8% between the 4 lb lateral and 5.5 lb 0 deg pitch. There was a significant statistical effect of onset rate in which NFxz recorded at 6 G/sec were greater than at 2 G/sec at +6, +8, and +10 Gz ($F > 5.8$, $p < 0.026$), though the mean differences were very small (averaging 0.2 lb). NFxz measured with the NDN

were significantly greater than the other actual helmet systems at each +Gz load ($F > 560$, $p < 0.001$). While there were statistical differences between AFT and NT at +4, 10, and +12 Gz, the mean differences were small (<1.5 lb).

29. For helicopter simulations (table B-23), NFxz grew significantly with increased weight at both +1.75 ($F = 56.2$, $p < 0.001$) and +4 Gz ($F = 234$, $p < 0.001$) levels. NFxz measured with the lateral weight configuration were significantly less than all pitches for both +1.75 ($F = 7.8$, $p = 0.002$) and +4 Gz ($F = 8.3$, $p = 0.002$) loads, whereas there were no differences between the pitches themselves. There were no statistically significant differences in NFxz between the three helmet systems.

30. NFxz for the 4 lb 90 deg pitch configuration were statistically significantly less (8 to 9%) than both the 0.5 and 1.5 lb asymmetric configurations for tactical +6 to +12 Gz loads ($F > 1214$, $p < 0.001$) and less than the 1.5 lb configuration at +4 Gz ($F = 13.0$, $p = 0.004$). Onset rate was not a significant factor in these comparisons. There were no differences at 0.5 G/sec.

31. Results of paired t-tests indicated that NFxz was significantly greater than HFxz for all tactical (37.2 ± 2.4%; $t = 158.5$, $p < 0.001$) and helicopter (49.5 ± 12.0%; $F = 64.1$, $p < 0.001$) simulations, including asymmetric tests (tactical: 37.4 ± 2.6%; $F = 328.7$, $p < 0.001$; helicopter: 48.3 ± 9.5%; $F = 162.0$, $p < 0.001$) at all +Gz loads.

32. Results of the ANOVA of the +10 Gz SACM runs indicated that NFxz during the SACM were greater at +4, +6, +8, and +10 Gz levels than the corresponding 5 sec plateau levels ($F > 10.9$, $p < 0.004$) (averaging 0.9 to 1.5 lb). There was also a statistical interaction between weight configurations and whether the run was a SACM or a 5 sec plateau for +4, +6, and +8 Gz loads ($F > 2.7$, $p < 0.048$). NFxz was statistically less during the first peak as compared to the second for +6 and +8 Gz loads ($F > 188.2$, $p < 0.001$) (table B-15).

HEAD MOMENTS

33. Head moment (HMy) increased with increasing +Gz load, pitch angle, weight, and onset rate (tables B-16 and B-17). HMy measured with the control configuration was essentially trivial compared with the other weight configurations. The relative peak increases in HMy, compared to the control, were 4 lb: 243 ± 20%; 4.5 lb: 465 ± 32%; 5 lb: 693 ± 63%; 5.5 lb: 927 ± 87%. HMy was the lowest with the lateral configuration and significantly increased as pitch angle increased from 0 to 90 deg for all +Gz loads ($F > 33000$, $p < 0.001$). There were significant differences in HMy between each weight position at every +Gz load (the lone exception was the 60 and 90 deg pitch at +10 Gz). HMy varied significantly with weight at each +Gz load ($F > 14000$, $p < 0.001$). There was also an interaction between weight and its position at each +Gz load as well ($F > 2200$, $p < 0.001$). The smallest moments were associated with 5 and 5.5 lb lateral configurations while the largest HMy were measured with the 5.5 lb in the 90 and 60 deg pitch positions. It is instructive to note the distribution of these interactions form roughly eight groups, which were fairly consistent regardless of +Gz level. Table 3 lists the mean and standard deviation of each group (from a through h) for each +Gz level, ranging from lowest to highest overall HMy and, within each group, the configurations are listed from smallest to greatest HMy as well.

Table 3: Clustering of HMy (in.-lb) Into Eight Groups for Five Weight Configurations

Mean ± 1 Standard Deviation HMy Per Group for Each +Gz Level							
Group	Configuration	Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
a	Lateral Lateral Lateral Lateral	5.0 5.5 4.5 4.0	2.6 ± 1.1	4.5 ± 1.6	7.1 ± 2.1	10.4 ± 2.6	14.6 ± 3.1
b	0 deg Pitch 0 deg Pitch	4.0 4.5	9.0 ± 1.2	14.8 ± 2.2	21.6 ± 3.4	29.8 ± 4.9	39.8 ± 7.0
c	0 deg Pitch 30 deg Pitch(1)	5.0 4.0	12.3 ± 0.7	20.2 ± 0.5	29.4 ± 0.0	40.7 ± 0.7	54.6 ± 2.1
d	0 deg Pitch(2) 90 deg Pitch 60 deg Pitch	5.5 4.0 4.0	15.9 ± 1.5	25.4 ± 1.5	36.2 ± 1.0	49.6 ± 1.0	65.7 ± 3.4
e	30 deg Pitch	4.5	20.1	32.1	46.3	63.3	82.7
f	60 deg Pitch 30 deg Pitch(3) 90 deg Pitch	4.5 5.0 4.5	27.2 ± 0.6	43.3 ± 1.0	62.3 ± 2.0	84.1 ± 3.1	107.8 ± 5.0
g	30 deg Pitch 60 deg Pitch 90 deg Pitch(4)	5.5 5.0 5.0	37.4 ± 2.3	60.4 ± 2.5	86.4 ± 2.1	114.8 ± 1.2	145.3 ± 0.4
h	60 deg Pitch 90 deg Pitch(5)	5.5 5.5	50.6 ± 1.4	81.0 ± 1.2	114.2 ± 0.3	149.0 ± 0.8	185.5 ± 2.3

NOTES: (1) 30 deg pitch < 0 deg pitch at +10 and +12 Gz.
(2) 0 deg pitch > 90 deg pitch and 60 deg pitch at +10 and +12 Gz.
(3) 30 deg pitch > 60 deg pitch and 90 deg pitch at +6 Gz and above.
(4) 90 deg pitch < 30 deg pitch and 60 deg pitch at +12 Gz.
(5) 90 deg pitch < 60 deg pitch at +10 and +12 Gz.

34. HMy was significantly less during the 6 G/sec compared to the 2 G/sec onset rates at each +Gz load ($F > 7.4$, $p < 0.014$). HMy measured with the JHMCS was significantly greater than the other actual helmet systems at each +Gz load while NDN was significantly less than the other systems ($F > 1540$, $p < 0.001$). The magnitude of the difference between JHMCS and NDN increased as +Gz level increased, averaging 69 ± 3%.

35. For helicopter simulations (table B-24), HMy significantly increased with higher weight at both +1.75 ($F = 7.64$, $p = 0.004$) and +4 Gz ($F = 7.85$, $p = 0.004$) levels. Post-hoc analysis indicated that the 6 lb weight was significantly greater than the other weights (averaging 66 ± 3% greater than the 4 lb), whereas there was no difference between the 4, 4.5, or 5 lb weights. HMy with lateral and 0 deg pitch configurations were significantly less than all pitches for both +1.75 ($F = 12.4$, $p < 0.001$) and +4 Gz ($F = 10.9$, $p < 0.001$) levels, whereas there were no differences between 30, 60, or 90 deg pitches. There was a 90 ± 1% difference between the lateral and the 90 deg pitch. NHV HMy was significantly greater than AH or NH ($F = 18.6$, $p = 0.008$).

36. HMy for the 1.5 lb asymmetric configuration was significantly greater (5 to 6%) than both the 4 lb 90 deg pitch and 0.5 lb asymmetric configuration for tactical +6 to +12 Gz loads ($F > 9.8$, $p < 0.009$). At +4 Gz, the 1.5 lb asymmetric was only greater than the 0.5 lb ($F = 6.5$, $p = 0.032$). HMy during 6 G/sec were statistically significantly lower than at 2 G/sec for +4 to +10 Gz loads ($F > 6.3$, $p < 0.046$), ranging from 5 to 1%, respectively. There were no differences at 0.5 G/sec.

37. There was a statistical interaction for HMy between pitch configurations and run type when comparing the +6, +8, and +10 Gz levels during the +10 Gz SACM to the corresponding 5 sec plateau levels ($F > 3.6$, $p < 0.015$) (table B-18). However, the magnitude of these relationships was small. Post-hoc analysis indicated that HMy was slightly greater (2%) during the +10 Gz SACM for the 30, 60, or 90 deg pitch configurations during +6 and +8 Gz levels and at the 90 deg pitch for the +10 Gz levels (1%) as compared to the corresponding 5 sec plateaus. A statistical interaction also was found between weight and run type for +6, +8, and +10 Gz levels. At +6 Gz, the 5 and 5.5 lb weights were 3% greater during the SACM ($F = 5.5$, $p = 0.004$), at +8 Gz, the 4.5, 5, and 5.5 lb weights were 2% greater ($F = 5.0$, $p = 0.004$), and at +10 Gz, the 4 lb 5 sec plateau value was 1% greater than the corresponding SACM moment ($F = 4.7$, $p = 0.02$). There was also a statistical interaction between the weight and whether it was the first or second SACM peak. During the +4 Gz peaks, the first peak was 9% greater than the second for the 4 and 4.5 lb weights ($F = 4.7$, $p = 0.016$). During the +6 Gz plateaus, the second peak was 2% greater at 5 and 5.5 lb, while the first peak was 4% greater for the 4 lb ($F = 11.8$, $p < 0.001$). For the +8 Gz peaks, the first peak was 2% less than the second and third for all weights ($F = 5.3$, $p = 0.001$). Finally, there was a significant interaction between weight configuration and peak number. During +6 Gz peaks, the second 30 and 60 deg pitch peaks were 2% greater than the first, while the lateral configuration first peak was 17% greater than the second ($F = 7.9$, $p = 0.002$). For the +8 Gz peaks, the first peak for each weight configuration was an average of 3% less than the second and third peaks ($F = 5.0$, $p = 0.001$).

NECK MOMENTS

38. Neck moment (NMy) was significantly affected by increasing +Gz load and weight, the pitch angle, and onset rate (tables B-19 and B-20). In a similar fashion to NFxz, when compared to the control configuration, the maximum relative change in NMy with each 0.5 lb increase in overall weight was very consistent at each +Gz load (4 lb: 17 ± 2%; 4.5 lb: 29 ± 3%; 5 lb: 41 ± 4%; 5.5 lb: 53 ± 5%). NMy varied significantly with overall weight at all +Gz levels, with the lateral configuration associated with the lowest NMy and 60 deg pitch with the highest ($F > 6055$, $p < 0.001$). NMy for each weight at each +Gz load was significantly different from each other, with 5.5 lb associated with the greatest NMy ($F > 7822$, $p < 0.001$). There was a statistical interaction between weight and its position at each +Gz load as well ($F > 632$, $p < 0.001$). The smallest moments were associated with 4 and 4.5 lb lateral configurations, while the largest NMy were measured with the 5.5 lb 90 and 60 deg pitch configurations. As with the HMy, the distribution of these interactions for NMy form into roughly nine groups, which were consistent regardless of the +Gz level. Table 4 lists the mean and standard deviation of each group (from a through i) for each +Gz level, ranging from lowest to highest overall HMy and, within each group, the configurations are listed from smallest to greatest HMy as well.

Table 4: Clustering of NMy (in.-lb) Into Nine Groups for Five Weight Configurations

Mean ± 1 Standard Deviation HMy Per Group for Each +Gz Level							
Group	Configuration	Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
a	Lateral Lateral	4.0 4.5	162.8 ± 4.3	285.5 ± 6.3	415.6 ± 8.7	553.7 ± 10.8	699.5 ± 12.7
b	Lateral 0 deg Pitch	5.0 4.0	171.9 ± 1.0	299.4 ± 2.3	435.0 ± 3.8	578.7 ± 5.3	729.6 ± 6.2
c	Lateral 90 deg Pitch 30 deg Pitch(1) 60 deg Pitch 0 deg Pitch	5.5 4.0 4.0 4.0 4.0	179.8 ± 2.0	312.3 ± 3.2	453.3 ± 4.3	602.8 ± 6.4	760.7 ± 8.1
d	0 deg Pitch 30 deg Pitch	5.0 4.5	193.3 ± 3.0	333.9 ± 2.8	483.9 ± 4.9	643.5 ± 6.2	812.3 ± 7.1
e	90 deg Pitch 0 deg Pitch(2) 60 deg Pitch	4.5 5.5 4.5	201.6 ± 1.3	346.8 ± 1.3	501.4 ± 2.7	666.8 ± 3.3	841.9 ± 7.7
f	30 deg Pitch	5.0	211.8	363.4	525.8	696.5	878.8
g	90 deg Pitch 60 deg Pitch	5.0 5.0	223.4 ± 0.6	381.0 ± 1.7	548.7 ± 2.5	724.7 ± 3.3	910.4 ± 6.6
h	30 deg Pitch	5.5	229.2	391.7	565.5	748.1	941.4
i	90 deg Pitch 60 deg Pitch	5.5 5.5	245.6 ± 1.6	416.2 ± 2.1	597.0 ± 4.4	784.4 ± 6.5	982.6 ± 8.7

NOTES: (1) 30 deg pitch < 90 deg pitch at +12 Gz.
(2) 60 deg pitch < 0 deg pitch at +10 and +12 Gz.

39. NMy was statistically significantly greater (1 to 2 in.-lb) during the 6 G/sec compared to the 2 G/sec onset rates from +4 to +10 Gz ($F > 5.6$, $p < 0.032$). NMy measured with the JHMCS was significantly greater than the other actual helmet systems while NDN was significantly greater than AFT and NT ($F > 433$, $p < 0.001$) at each +Gz load. NT was greater than AFT at +8 Gz and above. The magnitude of the difference between JHMCS and NDN increased with increasing +Gz loads, ranging from 6.1 to 31.6 in.-lb during +4 to +12 Gz, respectively, averaging 3.5 ± 0.4%.

40. For helicopter simulations (table B-24), NMy significantly increased with higher weight at both +1.75 ($F = 26.1$, $p < 0.001$) and +4 Gz ($F = 24.2$, $p < 0.001$) loads. Post-hoc analysis indicated NMy (at both +1.75 and 4 Gz) with the 6 lb weight was significantly greater than the other weights (averaging 33 ± 10% greater than the 4 lb). There were no differences between the 4 and 4.5 lb weights, while the 5 lb was greater than 4 lb. NMy with the lateral configuration was significantly less than 30, 60, and 90 deg pitches for both +1.75 ($F = 11.7$, $p < 0.001$) and +4 Gz ($F = 11.3$, $p < 0.001$) levels. NMy for the 0 deg pitch was also significantly less than the 60 and 90 deg pitches, whereas there were no differences between the 60 and 90 deg pitches. There was a 28 ± 8% difference between the lateral and the 60 and 90 deg pitches. There were no statistically significant differences in NMy between the three actual helmet systems.

41. NMy for the 4 lb 90 deg pitch configuration were statistically significantly less than both the 0.5 ($6 \pm 1\%$) and 1.5 lb ($12 \pm 1\%$) asymmetric configurations for tactical +4 to +12 Gz loads ($F > 312.5$, $p < 0.001$). Onset rate was not a significant factor in these comparisons. There were no differences at 0.5 G/sec.

42. Results of paired t-tests indicated that NMy was significantly greater than HMy for all tactical ($90.0 \pm 0.3\%$; $t = 112.7$, $p < 0.001$) and helicopter ($84.4 \pm 6.0\%$; $F = 40.3$, $p < 0.001$) simulations, including asymmetric tests (tactical: $92.1 \pm 0.3\%$; $F = 62.2$, $p < 0.001$; helicopter: $87.4 \pm 3.9\%$; $F = 11.5$, $p < 0.005$) at all +Gz levels.

43. Results of the ANOVA of the +10 Gz SACM runs indicated that NMy during the SACM were greater at +4 (4%), +6 (3%), +8 (2%), and +10 Gz (0.3%) levels than the corresponding 5 sec plateau levels ($F > 32.6$, $p < 0.001$). NMy during the second SACM peak at +4, +6, and +8 Gz were statistically greater than the first ($F > 1088$, $p < 0.001$). There was also a statistical interaction between weight position and whether it was the first or second SACM peak ($F > 3.0$, $p < 0.013$), which indicated that the trend towards lower NMy on the first peak was consistent for each configuration. This trend was also consistent according to the statistical interaction between peak number and weight for +4 and +6 Gz SACM peaks ($F > 5.8$, $p < 0.011$) (table B-21).

DISCUSSION

44. Schall (reference 10) indicated that flexion and extension injuries are produced at approximately 50% of the loads that can cause axial compression failure. He speculated that if the neck can support 200 lb, evidenced by native Africans who carry loads of produce daily on their heads, then the highest load flexion and extension load would be 100 lb (assuming symmetric loading in the Z-plane). He further calculated that if the head and helmet weighs 9.5-16 lb, at +9 Gz, a static load equivalent of 106-144 lb would be generated.

45. HFxz values measured in this experiment met and exceeded this theoretical limit between +8 and 10 Gz. Tactical helmet systems design “rules of thumb” set 4.5 lb as a maximum target weight. Figure 3 illustrates the range in HFxz for the 4.5 lb lateral and 60 deg pitch configurations, NDN, JHMCS, NT, and AFT in which the Schall threshold is exceeded.

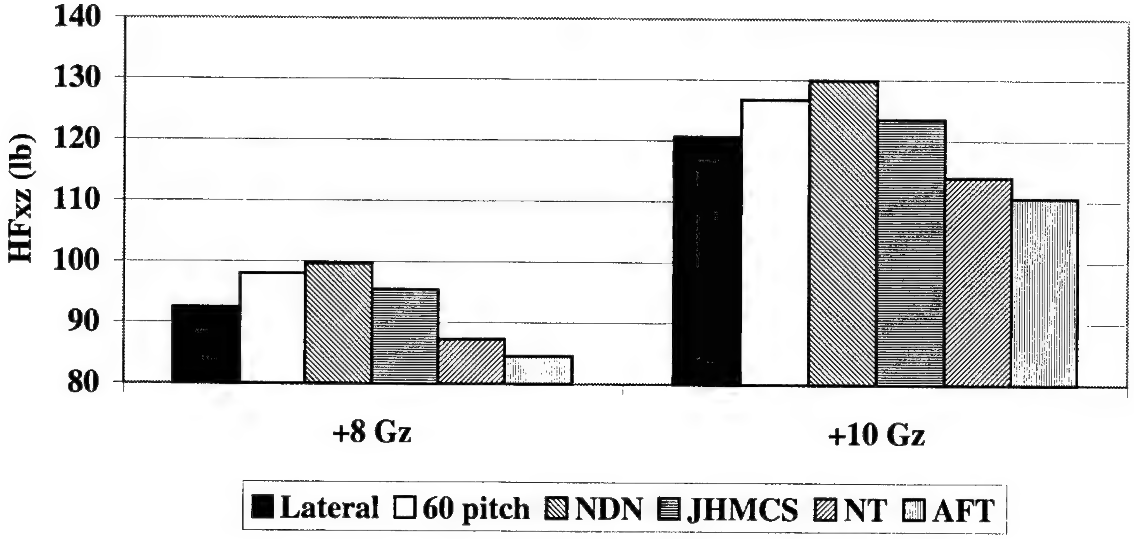


Figure 3: Illustration of How Measured HFxz (lb) Exceeds Schall 100 lb Injury Threshold Between +8 and +10 Gz for 4.5 lb Configurations and Actual Helmet Systems

46. In September 2000, the USN and USAF proposed compression and shear loads limits for impact/crash loads for a range of anthropometric sizes. These were derived based on the Mertz and Patrick (reference 11) load-duration curves measured from a series of cadaver (65-70 years old), manikin, and volunteer impact exposures. These curves were then modified to reflect Safety Center crash data and ATB simulation to increase the limits to more realistic, though still conservative, levels. For 80 msec impact load, compression and shear limits at the C0-C1 joint and compression limits at C7-T1 were 165 lb (107 lb female), 247 lb (mid-sized male), and 304 lb (223 lb male) and the C7-T1 joint shear limits were 330 lb (107 lb female), 494 lb (mid-sized male), and 608 lb (223 lb male). These values were not intended for the relatively long and low magnitude exposures of maneuvering flight. And one might speculate that, for the maneuvering environment with prolonged variable exposures, these levels may be conservative. However, it is the best information available today. Based on the manikin data, the small female HFxz level was met at +12 Gz for 5 lb systems. For neck compression, the small female limit was passed between +8 and +10 Gz at all weights and configurations and the mid-sized male limit was reached at +12 Gz for the 5.5 lb weight at all configurations.

47. Typically, the effects of +Gz stress and overall weight are the engineering design concerns for helmet systems. While this is certainly true for current platforms, as aircraft become more agile with the potential for multi-G vector flight, the effects of Gx and Gy become increasingly important considerations. As tables B-1, B-2, B-4, and B-5 indicate, as +Gz, onset rate, weight, and pitch angle increase, the effects of head Gx and Gy increase.

48. From a design perspective, the variation noted in these tests in peak NFxz for a given +Gz level, CG, and overall weight is of particular interest. This is in contrast to HFxz in which the peak values were typically associated with the 60 deg pitch configuration at each +Gz level and

weight and peak HMy and NMy occurred with the most forward pitch configurations. Knowledge of the change in distribution of the neck loads under the conditions tested in this study provides crucial information for developers of head-mounted systems.

49. The SACM profiles were included to determine the effects of a more realistic +Gz profile. From tables B-3, B-6, B-12, and B-21, we can see that HGx, HGy, HFxz, and NMy all increased with time during the profile. For example, when comparing +4 Gz peaks during the +10 Gz SACM with 4.5 lb weights, the average increase was 26% (HGx), 28% (HGy), 2% (HFxz), and 3% (NMy), while for the +8 Gz peaks, the average increase was 6% (HGx), 7% (HGy), 0.1% (HFxz), and 1% (NMy). It is unclear why this should be the case, given that there were no significant differences in the centrifuge profile between the repeated acceleration levels and there is no reason to expect the behavior of the rigidly restrained manikin to change over this short time period. Further, mean HGx and HGy values for all configurations were larger during the SACM as compared to the 5 sec plateaus. For example, mean increases during the +10 Gz SACM for 4.5 lb weights in the four pitch planes ranged from 34% to 5% (+4 Gz to +10 Gz) for HGx and 33% to 6% (+4 Gz to +10 Gz) for HGy. Whereas, HFxz, HMy, NFxz, and NMy were only slightly different, between +4 Gz to +10 Gz, HFxz ranged from 5% to 0.3%, HMy ranged from –6% to 0.1%, NFxz ranged from 1.6% to 0.2%, and NMy ranged from 5.9% to 0.3%.

50. However, injuries that may occur while wearing devices that cause the head to pitch forward during ACM may be more dependent on the increased moment than the overall load. For example, figure 4 demonstrates how HMy changes during the +10 Gz peak SACM for the tactical helmets. Note how the system with the greatest forward pitch (JHMCS) displays the highest HMy as +Gz increases. Furthermore, the data clearly demonstrate that a more balanced helmet display system, even with a higher overall weight (NDN), will be associated with lower HMy and NMy at the +Gz levels tested in this study than lower weight display systems (tables B-16 through B-21). The need for balanced weight distribution was also indicated by the fact that the asymmetric configurations were associated with higher HFxz, NFxz, and NMy than the corresponding balanced configuration.

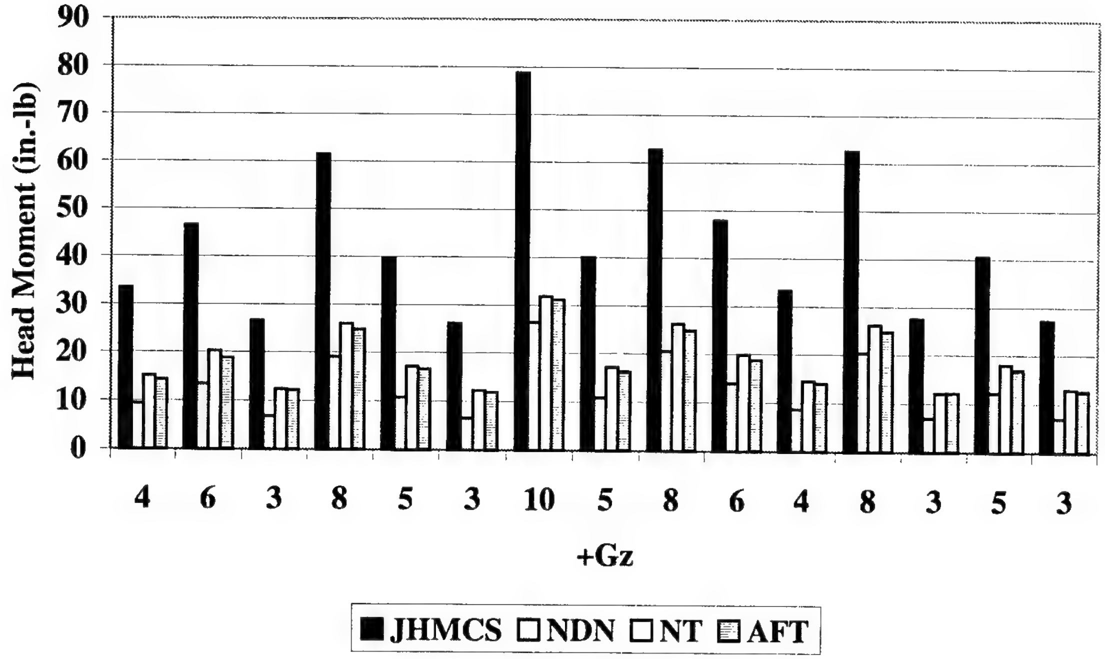


Figure 4: Head Moment (in.-lb) Measured While the Manikin Wore Four Types of Tactical Helmet Systems during +10 Gz Peak Gillingham SACM

CONCLUSIONS

51. One area of critical importance in the design of head mounted protective and helmet display systems is the effect of added weight and its impact on CG during exposures to the everyday +Gz levels and onset rates experienced by aircrew. This report details how the acceleration vectors, resultant forces, and moments measured at the base of the head and neck are affected under conditions mimicking high performance fixed and rotary wing flight. HGx (forward acceleration) reaches a peak when weight is positioned at 60 deg pitch, HGy (lateral acceleration) peaks between 0 and 30 deg pitch, while HGz (axial acceleration) is greatest with weight distributed laterally and was the least at the 60 deg pitch position. HFxz, HMy, NFxz, and NMy increased as the weight was pitched forward as compared to similarly weighted loads distributed laterally. The greater loads and moments generated at the neck emphasize the need for balanced weighted designs to mitigate the risk of injury.

52. Furthermore, the results of the asymmetric configurations, the relationship between balanced configurations and reduction in moments of inertia (e.g., NDN versus JHMCS), and the increased loading and moments associated with more forward pitch configurations all emphasize a crucial systems design consideration. When the weight and CG of current and developmental head mounted systems are considered, it is essential to account for *every* element supported by the head and neck. This includes the helmet, visor, oxygen mask, hoses, communications cords, additional displays, chemical-biological protective hood, etc. Each of these items increases the overall weight and its distribution and affects the ability of the neck to support the system and must be included in any injury tolerance assessment to both maneuvering and impact/crash acceleration exposures.

53. Future efforts include a modification of the Articulated Total Body (ATB) model using the experimental results to make it applicable for use in the maneuvering acceleration environment. The ATB model is designed for impact rather than maneuvering acceleration. ATB has joint properties that can accurately model human and manikin response. It is anticipated that the model will need the following modifications:

a. Split the pelvis into two segments in order to provide needed stability for long duration events (exposures lasting seconds rather than milliseconds).

b. Modify seat deformation properties to reflect actual event.

c. Lock the neck joint to simulate the rigid neck used in the experimental series.

54. Once accomplished, the control conditions simulated in this experiment will be simulated in ATB to predict head accelerations and head and neck loads and moments. Once the model accurately reproduces these conditions, the various head supported mass configurations used in this study will be used to validate the model. The enhanced model could then be used to expand the envelope of tested weight and CG ranges, as well as levels of peak G and onset rates to further define the physiologic effects on the cervical spine.

RECOMMENDATIONS

55. Perform an additional series of tests using the tactical helmet loads and configurations while exposed to simulated catapult and arrestment ($\pm$Gx) and lateral ($\pm$Gy) acceleration stresses.

56. Perform an additional series of tests with other types of actual helmet systems, including those equipped with tactical night vision goggles and chemical-biological protective headgear.

57. Conduct the modeling described in paragraphs 53 and 54.

58. Future safety designs should recognize the importance of moment of inertia in addition to overall weight, as indicated in paragraphs 49 and 50.

59. Future safety designs should recognize the importance of the contributions of the entire suite of head supported equipment, not just the helmet itself, in determining the injury risk of exposures to both maneuvering and impact/crash acceleration, as indicated in paragraph 52.

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APPENDIX A
LIST OF TEST TEAM MEMBERS

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APPENDIX B
TABLES

Table B-1: Mean ± One Standard Deviation HGx (G) for Tactical Lateral and Pitch Configurations and Helmet Systems at 2 G/sec Onset Rate

HGx was statistically significantly different based on pitch configuration and weight for each +Gz load ($p < 0.001$). There was also a statistical interaction between configuration and weight at each +Gz load ($p < 0.001$). *: +4 Gz ($p = 0.011$) and +6 Gz ($p = 0.045$) asymmetric HGx different from 4 lb 90 deg pitch. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	0.24 ± 0.01	0.46 ± 0.01	0.74 ± 0.01	1.08 ± 0.02	1.48 ± 0.01
Lateral	4.0	0.27 ± 0.01	0.49 ± 0.01	0.77 ± 0.01	1.10 ± 0.02	1.49 ± 0.01
0 deg Pitch	4.0	0.36 ± 0.01	0.64 ± 0.01	0.98 ± 0.01	1.41 ± 0.02	1.92 ± 0.01
30 deg Pitch	4.0	0.38 ± 0.01	0.68 ± 0.01	1.09 ± 0.01	1.60 ± 0.02	2.20 ± 0.01
60 deg Pitch	4.0	0.37 ± 0.01	0.69 ± 0.01	1.11 ± 0.01	1.65 ± 0.02	2.26 ± 0.01
90 deg Pitch	4.0	0.32 ± 0.01*	0.61 ± 0.01	1.00 ± 0.01	1.49 ± 0.01	2.09 ± 0.01
Lateral	4.5	0.27 ± 0.01	0.50 ± 0.01	0.77 ± 0.01	1.10 ± 0.02	1.48 ± 0.01
0 deg Pitch	4.5	0.36 ± 0.01	0.65 ± 0.01	1.00 ± 0.01	1.47 ± 0.01	2.05 ± 0.01
30 deg Pitch	4.5	0.39 ± 0.01	0.73 ± 0.01	1.19 ± 0.01	1.76 ± 0.01	2.41 ± 0.01
60 deg Pitch	4.5	0.42 ± 0.01	0.80 ± 0.01	1.30 ± 0.01	1.89 ± 0.02	2.56 ± 0.01
90 deg Pitch	4.5	0.38 ± 0.01	0.75 ± 0.01	1.23 ± 0.01	1.81 ± 0.01	2.47 ± 0.01
Lateral	5.0	0.27 ± 0.01	0.50 ± 0.01	0.76 ± 0.02	1.08 ± 0.02	1.45 ± 0.01
0 deg Pitch	5.0	0.37 ± 0.01	0.68 ± 0.01	1.06 ± 0.01	1.57 ± 0.01	2.19 ± 0.01
30 deg Pitch	5.0	0.43 ± 0.01	0.83 ± 0.01	1.35 ± 0.01	1.94 ± 0.01	2.63 ± 0.01
60 deg Pitch	5.0	0.47 ± 0.01	0.92 ± 0.01	1.47 ± 0.01	2.09 ± 0.01	2.77 ± 0.01
90 deg Pitch	5.0	0.45 ± 0.01	0.88 ± 0.01	1.42 ± 0.01	2.03 ± 0.02	2.70 ± 0.01
Lateral	5.5	0.28 ± 0.01	0.51 ± 0.01	0.78 ± 0.02	1.11 ± 0.02	1.50 ± 0.01
0 deg Pitch	5.5	0.38 ± 0.01	0.69 ± 0.01	1.10 ± 0.01	1.66 ± 0.01	2.31 ± 0.01
30 deg Pitch	5.5	0.47 ± 0.01	0.93 ± 0.01	1.49 ± 0.01	2.13 ± 0.01	2.81 ± 0.01
60 deg Pitch	5.5	0.54 ± 0.01	1.04 ± 0.01	1.63 ± 0.01	2.26 ± 0.02	2.94 ± 0.01
90 deg Pitch	5.5	0.52 ± 0.01	1.01 ± 0.01	1.57 ± 0.02	2.17 ± 0.02	2.86 ± 0.01
0.5 lb Right	4.5 Asymmetric	0.42 ± 0.01*	0.75 ± 0.01*	1.19 ± 0.02	1.75 ± 0.02	2.37 ± 0.01
1.5 lb Right	5.5 Asymmetric	0.41 ± 0.01*	0.75 ± 0.01*	1.18 ± 0.02	1.68 ± 0.02	2.32 ± 0.01
0.5 lb Left	4.5 Asymmetric	0.40 ± 0.01*	0.72 ± 0.01*	1.13 ± 0.01	1.63 ± 0.01	2.22 ± 0.01
1.5 lb Left	5.5 Asymmetric	0.38 ± 0.01*	0.67 ± 0.01*	1.03 ± 0.01	1.46 ± 0.01	2.00 ± 0.01
JHMCS	4.1	0.48 ± 0.01	0.87 ± 0.01	1.36 ± 0.01	1.97 ± 0.01	2.69 ± 0.01
NDN	5.4	0.39 ± 0.01	0.68 ± 0.01	1.02 ± 0.01	1.43 ± 0.01	1.93 ± 0.01
NT	3.0	0.40 ± 0.01	0.71 ± 0.01	1.08 ± 0.02	1.52 ± 0.01	2.05 ± 0.01
AFT	3.3	0.43 ± 0.01	0.75 ± 0.01	1.13 ± 0.01	1.56 ± 0.02	2.06 ± 0.01

Table B-2: Mean ± One Standard Deviation HGx (G) for Tactical Lateral and Pitch Configurations and Helmet Systems at 6 G/sec Onset Rate

HGx was statistically significantly different based on pitch configuration and weight for each +Gz load ($p < 0.001$). There was a statistical interaction between configuration and weight at each +Gz load ($p < 0.001$) and an interaction between configuration and onset rate at +4 (all pitches), 6 (lateral and pitches), 8 (lateral and pitches), and 10 (all pitches) Gz ($p < 0.02$). NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	0.26 ± 0.01	0.50 ± 0.01	0.78 ± 0.01	1.12 ± 0.02	1.54 ± 0.02
Lateral	4.0	0.27 ± 0.01	0.51 ± 0.01	0.79 ± 0.02	1.10 ± 0.02	1.51 ± 0.02
0 deg Pitch	4.0	0.37 ± 0.01	0.66 ± 0.01	1.01 ± 0.01	1.42 ± 0.02	1.93 ± 0.02
30 deg Pitch	4.0	0.40 ± 0.01	0.72 ± 0.01	1.15 ± 0.01	1.61 ± 0.01	2.11 ± 0.03
60 deg Pitch	4.0	0.39 ± 0.01	0.72 ± 0.01	1.13 ± 0.01	1.65 ± 0.02	2.27 ± 0.03
90 deg Pitch	4.0	0.35 ± 0.01	0.66 ± 0.01	1.05 ± 0.01	1.54 ± 0.02	2.12 ± 0.02
Lateral	4.5	0.28 ± 0.01	0.51 ± 0.01	0.79 ± 0.01	1.10 ± 0.02	1.50 ± 0.02
0 deg Pitch	4.5	0.38 ± 0.01	0.68 ± 0.01	1.06 ± 0.01	1.50 ± 0.01	2.06 ± 0.01
30 deg Pitch	4.5	0.42 ± 0.01	0.77 ± 0.01	1.23 ± 0.01	1.77 ± 0.01	2.41 ± 0.02
60 deg Pitch	4.5	0.45 ± 0.01	0.84 ± 0.01	1.35 ± 0.01	1.93 ± 0.02	2.58 ± 0.01
90 deg Pitch	4.5	0.42 ± 0.01	0.81 ± 0.01	1.29 ± 0.01	1.87 ± 0.02	2.50 ± 0.02
Lateral	5.0	0.28 ± 0.01	0.51 ± 0.01	0.79 ± 0.01	1.10 ± 0.02	1.45 ± 0.02
0 deg Pitch	5.0	0.40 ± 0.01	0.71 ± 0.01	1.12 ± 0.01	1.59 ± 0.01	2.17 ± 0.01
30 deg Pitch	5.0	0.46 ± 0.01	0.87 ± 0.01	1.38 ± 0.01	1.97 ± 0.01	2.65 ± 0.01
60 deg Pitch	5.0	0.51 ± 0.01	0.96 ± 0.01	1.51 ± 0.01	2.13 ± 0.02	2.82 ± 0.02
90 deg Pitch	5.0	0.49 ± 0.01	0.93 ± 0.01	1.47 ± 0.02	2.07 ± 0.02	2.72 ± 0.02
Lateral	5.5	0.28 ± 0.01	0.53 ± 0.01	0.80 ± 0.01	1.13 ± 0.02	1.49 ± 0.02
0 deg Pitch	5.5	0.40 ± 0.01	0.74 ± 0.01	1.17 ± 0.01	1.69 ± 0.01	2.36 ± 0.02
30 deg Pitch	5.5	0.51 ± 0.01	0.96 ± 0.01	1.52 ± 0.01	2.13 ± 0.01	2.82 ± 0.02
60 deg Pitch	5.5	0.57 ± 0.01	1.07 ± 0.01	1.67 ± 0.01	2.30 ± 0.02	2.97 ± 0.01
90 deg Pitch	5.5	0.53 ± 0.04	1.04 ± 0.01	1.62 ± 0.02	2.23 ± 0.02	2.90 ± 0.01
0.5 lb Right	4.5 Asymmetric	0.45 ± 0.02	0.79 ± 0.01	1.22 ± 0.01	1.76 ± 0.02	2.38 ± 0.02
1.5 lb Right	5.5 Asymmetric	0.45 ± 0.01	0.80 ± 0.01	1.20 ± 0.02	1.72 ± 0.02	2.31 ± 0.02
0.5 lb Left	4.5 Asymmetric	0.42 ± 0.01	0.75 ± 0.01	1.15 ± 0.01	1.62 ± 0.01	2.25 ± 0.03
1.5 lb Left	5.5 Asymmetric	0.40 ± 0.01	0.72 ± 0.01	1.07 ± 0.01	1.48 ± 0.01	2.03 ± 0.01
JHMCS	4.1	0.53 ± 0.01	0.94 ± 0.01	1.41 ± 0.01	2.00 ± 0.01	2.69 ± 0.01
NDN	5.4	0.41 ± 0.01	0.71 ± 0.01	1.07 ± 0.01	1.48 ± 0.01	1.95 ± 0.01
NT	3.0	0.43 ± 0.01	0.74 ± 0.01	1.11 ± 0.02	1.53 ± 0.01	2.02 ± 0.01
AFT	3.3	0.44 ± 0.01	0.76 ± 0.01	1.13 ± 0.01	1.54 ± 0.02	2.04 ± 0.01

Table B-3: HGx (G) (± One Standard Deviation) during +10 Gz SACM at +4, 6, 8, and 10 Gz Plateaus for the Tactical Lateral and Pitch Configurations and Helmet Systems

+8 Gz second plateau value represents the mean of the 2nd and 3rd repetitions. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
Control	3.5	0.27 ± 0.02	0.33 ± 0.02	0.51 ± 0.02	0.60 ± 0.02	0.81 ± 0.03	0.85 ± 0.04	1.18 ± 0.03
Lateral	4.0	0.27 ± 0.02	0.32 ± 0.02	0.51 ± 0.02	0.60 ± 0.02	0.81 ± 0.04	0.85 ± 0.04	1.16 ± 0.04
0 deg Pitch	4.0	0.37 ± 0.01	0.45 ± 0.01	0.67 ± 0.01	0.79 ± 0.02	1.04 ± 0.03	1.11 ± 0.03	1.49 ± 0.03
30 deg Pitch	4.0	0.37 ± 0.01	0.46 ± 0.01	0.71 ± 0.01	0.84 ± 0.02	1.12 ± 0.03	1.20 ± 0.03	1.61 ± 0.03
60 deg Pitch	4.0	0.38 ± 0.01	0.50 ± 0.01	0.74 ± 0.01	0.89 ± 0.02	1.18 ± 0.03	1.27 ± 0.03	1.61 ± 0.03
90 deg Pitch	4.0	0.35 ± 0.01	0.46 ± 0.02	0.67 ± 0.02	0.83 ± 0.02	1.09 ± 0.04	1.18 ± 0.04	1.58 ± 0.04
Lateral	4.5	0.28 ± 0.02	0.33 ± 0.02	0.51 ± 0.01	0.60 ± 0.02	0.81 ± 0.03	0.85 ± 0.04	1.14 ± 0.03
0 deg Pitch	4.5	0.38 ± 0.01	0.47 ± 0.01	0.70 ± 0.01	0.83 ± 0.02	1.09 ± 0.02	1.16 ± 0.02	1.56 ± 0.03
30 deg Pitch	4.5	0.42 ± 0.01	0.53 ± 0.01	0.81 ± 0.01	0.95 ± 0.02	1.27 ± 0.03	1.35 ± 0.02	1.83 ± 0.03
60 deg Pitch	4.5	0.45 ± 0.01	0.58 ± 0.01	0.86 ± 0.01	1.03 ± 0.02	1.37 ± 0.03	1.46 ± 0.03	1.95 ± 0.03
90 deg Pitch	4.5	0.42 ± 0.01	0.56 ± 0.01	0.83 ± 0.02	1.00 ± 0.02	1.33 ± 0.03	1.42 ± 0.04	1.91 ± 0.03
Lateral	5.0	0.28 ± 0.01	0.33 ± 0.02	0.51 ± 0.02	0.59 ± 0.02	0.79 ± 0.04	0.83 ± 0.04	1.12 ± 0.03
0 deg Pitch	5.0	0.39 ± 0.01	0.49 ± 0.01	0.72 ± 0.01	0.87 ± 0.01	1.14 ± 0.02	1.21 ± 0.02	1.62 ± 0.02
30 deg Pitch	5.0	0.46 ± 0.01	0.59 ± 0.01	0.89 ± 0.01	1.05 ± 0.01	1.41 ± 0.02	1.49 ± 0.02	2.01 ± 0.02
60 deg Pitch	5.0	0.51 ± 0.01	0.66 ± 0.01	0.99 ± 0.02	1.15 ± 0.02	1.55 ± 0.03	1.63 ± 0.03	2.16 ± 0.04
90 deg Pitch	5.0	0.49 ± 0.01	0.64 ± 0.01	0.95 ± 0.02	1.11 ± 0.02	1.50 ± 0.03	1.58 ± 0.04	2.10 ± 0.04
Lateral	5.5	0.29 ± 0.02	0.33 ± 0.02	0.52 ± 0.02	0.60 ± 0.02	0.81 ± 0.04	0.85 ± 0.04	1.15 ± 0.04
0 deg Pitch	5.5	0.40 ± 0.01	0.53 ± 0.01	0.76 ± 0.01	0.93 ± 0.01	1.19 ± 0.02	1.29 ± 0.02	1.72 ± 0.02
30 deg Pitch	5.5	0.51 ± 0.01	0.65 ± 0.01	0.97 ± 0.01	1.15 ± 0.01	1.53 ± 0.02	1.62 ± 0.02	2.16 ± 0.02
60 deg Pitch	5.5	0.58 ± 0.01	0.73 ± 0.02	1.10 ± 0.01	1.25 ± 0.02	1.68 ± 0.03	1.75 ± 0.03	2.31 ± 0.03
90 deg Pitch	5.5	0.56 ± 0.01	0.71 ± 0.02	1.07 ± 0.02	1.22 ± 0.04	1.65 ± 0.04	1.72 ± 0.04	2.27 ± 0.04

Table B-3 (Cont'd)

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
0.5 lb Right	4.5 Asymmetric	0.43 ± 0.01	0.53 ± 0.01	0.80 ± 0.02	0.93 ± 0.03	1.26 ± 0.03	1.34 ± 0.02	1.79 ± 0.03
1.5 lb Right	5.5 Asymmetric	0.44 ± 0.02	0.54 ± 0.01	0.81 ± 0.02	0.95 ± 0.02	1.27 ± 0.04	1.35 ± 0.04	1.80 ± 0.04
0.5 lb Left	4.5 Asymmetric	0.42 ± 0.02	0.53 ± 0.02	0.78 ± 0.01	0.93 ± 0.02	1.22 ± 0.03	1.30 ± 0.03	1.72 ± 0.03
1.5 lb Left	5.5 Asymmetric	0.42 ± 0.01	0.54 ± 0.02	0.77 ± 0.01	0.94 ± 0.04	1.22 ± 0.04	1.31 ± 0.04	1.73 ± 0.03
JHMCS	4.1	0.53 ± 0.01	0.65 ± 0.02	0.95 ± 0.02	1.11 ± 0.02	1.47 ± 0.03	1.56 ± 0.04	2.07 ± 0.03
NDN	5.4	0.42 ± 0.01	0.51 ± 0.01	0.73 ± 0.01	0.87 ± 0.01	1.09 ± 0.02	1.18 ± 0.02	1.53 ± 0.02
NT	3.0	0.43 ± 0.01	0.52 ± 0.03	0.76 ± 0.02	0.88 ± 0.02	1.14 ± 0.04	1.22 ± 0.05	1.61 ± 0.04
AFT	3.3	0.44 ± 0.01	0.51 ± 0.03	0.76 ± 0.02	0.88 ± 0.02	1.15 ± 0.05	1.22 ± 0.05	1.61 ± 0.04

Table B-4: Mean ± One Standard Deviation HGy (G) for Tactical Lateral and Pitch Configurations and Helmet Systems at 2 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	-0.21 ± 0.01	-0.26 ± 0.01	-0.38 ± 0.01	-0.52 ± 0.01	-0.70 ± 0.02
Lateral	4.0	-0.27 ± 0.01	-0.35 ± 0.01	-0.46 ± 0.01	-0.60 ± 0.01	-0.78 ± 0.02
0 deg Pitch	4.0	-0.34 ± 0.00	-0.47 ± 0.00	-0.61 ± 0.00	-0.78 ± 0.01	-0.98 ± 0.01
30 deg Pitch	4.0	-0.34 ± 0.01	-0.45 ± 0.01	-0.59 ± 0.01	-0.76 ± 0.01	-0.96 ± 0.01
60 deg Pitch	4.0	-0.33 ± 0.01	-0.45 ± 0.01	-0.59 ± 0.01	-0.76 ± 0.01	-0.97 ± 0.01
90 deg Pitch	4.0	-0.30 ± 0.01	-0.39 ± 0.01	-0.51 ± 0.01	-0.67 ± 0.01	-0.85 ± 0.02
Lateral	4.5	-0.29 ± 0.01	-0.37 ± 0.01	-0.50 ± 0.01	-0.63 ± 0.01	-0.80 ± 0.01
0 deg Pitch	4.5	-0.35 ± 0.00	-0.47 ± 0.00	-0.61 ± 0.00	-0.79 ± 0.00	-0.99 ± 0.01
30 deg Pitch	4.5	-0.33 ± 0.00	-0.45 ± 0.01	-0.60 ± 0.01	-0.79 ± 0.02	-0.99 ± 0.02
60 deg Pitch	4.5	-0.33 ± 0.01	-0.43 ± 0.01	-0.57 ± 0.01	-0.74 ± 0.02	-0.94 ± 0.01
90 deg Pitch	4.5	-0.31 ± 0.00	-0.40 ± 0.01	-0.53 ± 0.01	-0.69 ± 0.01	-0.88 ± 0.01
Lateral	5.0	-0.30 ± 0.01	-0.39 ± 0.01	-0.51 ± 0.01	-0.66 ± 0.02	-0.84 ± 0.01
0 deg Pitch	5.0	-0.36 ± 0.00	-0.49 ± 0.00	-0.63 ± 0.00	-0.80 ± 0.01	-1.01 ± 0.01
30 deg Pitch	5.0	-0.36 ± 0.01	-0.48 ± 0.01	-0.64 ± 0.01	-0.81 ± 0.01	-1.02 ± 0.02
60 deg Pitch	5.0	-0.33 ± 0.01	-0.45 ± 0.01	-0.59 ± 0.01	-0.76 ± 0.01	-0.97 ± 0.01
90 deg Pitch	5.0	-0.30 ± 0.01	-0.40 ± 0.01	-0.54 ± 0.01	-0.71 ± 0.02	-0.90 ± 0.02
Lateral	5.5	-0.30 ± 0.01	-0.39 ± 0.01	-0.52 ± 0.01	-0.67 ± 0.01	-0.86 ± 0.01
0 deg Pitch	5.5	-0.36 ± 0.00	-0.49 ± 0.00	-0.62 ± 0.00	-0.82 ± 0.01	-1.03 ± 0.00
30 deg Pitch	5.5	-0.29 ± 0.01	-0.42 ± 0.01	-0.57 ± 0.01	-0.77 ± 0.01	-1.00 ± 0.01
60 deg Pitch	5.5	-0.34 ± 0.01	-0.47 ± 0.01	-0.62 ± 0.01	-0.80 ± 0.01	-1.01 ± 0.02
90 deg Pitch	5.5	-0.31 ± 0.01	-0.43 ± 0.01	-0.57 ± 0.01	-0.71 ± 0.01	-0.93 ± 0.02
0.5 lb Right	4.5 Asymmetric	-0.16 ± 0.01	-0.20 ± 0.01	-0.29 ± 0.02	-0.43 ± 0.02	-0.64 ± 0.01
1.5 lb Right	5.5 Asymmetric	-0.26 ± 0.01	-0.32 ± 0.01	-0.40 ± 0.02	-0.49 ± 0.02	-0.63 ± 0.01
0.5 lb Left	4.5 Asymmetric	-0.33 ± 0.01	-0.45 ± 0.01	-0.58 ± 0.01	-0.76 ± 0.01	-0.97 ± 0.01
1.5 lb Left	5.5 Asymmetric	-0.35 ± 0.01	-0.48 ± 0.01	-0.63 ± 0.01	-0.82 ± 0.01	-1.07 ± 0.01
JHMCS	4.1	-0.10 ± 0.01	-0.07 ± 0.01	-0.12 ± 0.01	-0.27 ± 0.01	-0.46 ± 0.02
NDN	5.4	-0.26 ± 0.01	-0.35 ± 0.01	-0.45 ± 0.01	-0.58 ± 0.01	-0.74 ± 0.02
NT	3.0	-0.20 ± 0.01	-0.27 ± 0.01	-0.37 ± 0.01	-0.47 ± 0.01	-0.62 ± 0.02
AFT	3.3	-0.11 ± 0.01	-0.15 ± 0.01	-0.22 ± 0.01	-0.32 ± 0.02	-0.48 ± 0.02

Table B-5: Mean ± One Standard Deviation HGy (G) for Tactical Lateral and Pitch Configurations and Helmet Systems at 6 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	-0.27 ± 0.04	-0.37 ± 0.01	-0.47 ± 0.01	-0.58 ± 0.01	-0.75 ± 0.02
Lateral	4.0	-0.28 ± 0.08	-0.39 ± 0.02	-0.49 ± 0.01	-0.61 ± 0.01	-0.79 ± 0.02
0 deg Pitch	4.0	-0.41 ± 0.01	-0.51 ± 0.01	-0.64 ± 0.01	-0.79 ± 0.01	-0.99 ± 0.01
30 deg Pitch	4.0	-0.33 ± 0.10	-0.47 ± 0.01	-0.62 ± 0.01	-0.78 ± 0.01	-0.93 ± 0.03
60 deg Pitch	4.0	-0.30 ± 0.10	-0.44 ± 0.03	-0.56 ± 0.01	-0.70 ± 0.01	-0.90 ± 0.03
90 deg Pitch	4.0	-0.33 ± 0.11	-0.43 ± 0.02	-0.54 ± 0.01	-0.68 ± 0.02	-0.86 ± 0.01
Lateral	4.5	-0.30 ± 0.08	-0.41 ± 0.03	-0.51 ± 0.01	-0.64 ± 0.01	-0.82 ± 0.02
0 deg Pitch	4.5	-0.40 ± 0.01	-0.49 ± 0.00	-0.64 ± 0.00	-0.81 ± 0.00	-1.01 ± 0.01
30 deg Pitch	4.5	-0.36 ± 0.07	-0.50 ± 0.02	-0.64 ± 0.01	-0.80 ± 0.02	-1.01 ± 0.01
60 deg Pitch	4.5	-0.34 ± 0.12	-0.47 ± 0.03	-0.60 ± 0.01	-0.76 ± 0.02	-0.96 ± 0.02
90 deg Pitch	4.5	-0.31 ± 0.09	-0.44 ± 0.03	-0.55 ± 0.01	-0.69 ± 0.01	-0.88 ± 0.02
Lateral	5.0	-0.29 ± 0.09	-0.41 ± 0.01	-0.54 ± 0.01	-0.66 ± 0.02	-0.84 ± 0.02
0 deg Pitch	5.0	-0.36 ± 0.01	-0.51 ± 0.00	-0.65 ± 0.01	-0.82 ± 0.00	-1.02 ± 0.01
30 deg Pitch	5.0	-0.36 ± 0.09	-0.50 ± 0.04	-0.66 ± 0.01	-0.82 ± 0.01	-1.04 ± 0.02
60 deg Pitch	5.0	-0.33 ± 0.11	-0.48 ± 0.03	-0.62 ± 0.01	-0.78 ± 0.02	-0.99 ± 0.02
90 deg Pitch	5.0	-0.36 ± 0.09	-0.44 ± 0.02	-0.57 ± 0.01	-0.72 ± 0.01	-0.90 ± 0.02
Lateral	5.5	-0.34 ± 0.11	-0.42 ± 0.02	-0.54 ± 0.01	-0.68 ± 0.02	-0.85 ± 0.01
0 deg Pitch	5.5	-0.41 ± 0.01	-0.51 ± 0.00	-0.66 ± 0.00	-0.83 ± 0.01	-0.92 ± 0.01
30 deg Pitch	5.5	-0.36 ± 0.10	-0.50 ± 0.01	-0.65 ± 0.01	-0.82 ± 0.02	-1.04 ± 0.02
60 deg Pitch	5.5	-0.35 ± 0.08	-0.49 ± 0.02	-0.64 ± 0.01	-0.80 ± 0.01	-1.02 ± 0.01
90 deg Pitch	5.5	-0.38 ± 0.08	-0.46 ± 0.03	-0.59 ± 0.01	-0.75 ± 0.02	-0.95 ± 0.02
0.5 lb Right	4.5 Asymmetric	-0.24 ± 0.02	-0.39 ± 0.01	-0.49 ± 0.01	-0.61 ± 0.02	-0.82 ± 0.02
1.5 lb Right	5.5 Asymmetric	-0.31 ± 0.01	-0.34 ± 0.01	-0.42 ± 0.02	-0.51 ± 0.02	-0.63 ± 0.02
0.5 lb Left	4.5 Asymmetric	-0.41 ± 0.01	-0.50 ± 0.01	-0.64 ± 0.01	-0.78 ± 0.01	-0.85 ± 0.03
1.5 lb Left	5.5 Asymmetric	-0.38 ± 0.01	-0.53 ± 0.01	-0.68 ± 0.01	-0.85 ± 0.01	-0.93 ± 0.01
JHMCS	4.1	-0.21 ± 0.04	-0.27 ± 0.02	-0.30 ± 0.02	-0.40 ± 0.02	-0.55 ± 0.02
NDN	5.4	-0.33 ± 0.09	-0.39 ± 0.02	-0.48 ± 0.02	-0.61 ± 0.01	-0.77 ± 0.03
NT	3.0	-0.27 ± 0.07	-0.34 ± 0.02	-0.41 ± 0.02	-0.52 ± 0.01	-0.66 ± 0.02
AFT	3.3	-0.24 ± 0.10	-0.28 ± 0.02	-0.34 ± 0.02	-0.44 ± 0.02	-0.58 ± 0.02

Table B-6: HGy (G) (± One Standard Deviation) during +10 Gz SACM at +4, 6, 8, and 10 Gz Plateaus for the Tactical Lateral and Pitch Configurations and Helmet Systems

+8 Gz second plateau value represents the mean of the 2nd and 3rd repetitions. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
Control	3.5	-0.28 ± 0.01	-0.37 ± 0.01	-0.39 ± 0.01	-0.46 ± 0.01	-0.50 ± 0.01	-0.55 ± 0.01	-0.64 ± 0.01
Lateral	4.0	-0.28 ± 0.01	-0.38 ± 0.01	-0.40 ± 0.01	-0.47 ± 0.01	-0.51 ± 0.01	-0.57 ± 0.01	-0.64 ± 0.01
0 deg Pitch	4.0	-0.36 ± 0.01	-0.45 ± 0.01	-0.50 ± 0.01	-0.57 ± 0.01	-0.64 ± 0.02	-0.69 ± 0.01	-0.81 ± 0.01
30 deg Pitch	4.0	-0.33 ± 0.01	-0.44 ± 0.01	-0.48 ± 0.01	-0.56 ± 0.01	-0.62 ± 0.01	-0.68 ± 0.01	-0.80 ± 0.01
60 deg Pitch	4.0	-0.32 ± 0.01	-0.43 ± 0.01	-0.46 ± 0.01	-0.54 ± 0.01	-0.59 ± 0.01	-0.65 ± 0.01	-0.76 ± 0.01
90 deg Pitch	4.0	-0.31 ± 0.01	-0.40 ± 0.01	-0.43 ± 0.01	-0.50 ± 0.01	-0.55 ± 0.01	-0.60 ± 0.01	-0.71 ± 0.01
Lateral	4.5	-0.30 ± 0.01	-0.42 ± 0.01	-0.39 ± 0.01	-0.49 ± 0.01	-0.54 ± 0.01	-0.59 ± 0.01	-0.69 ± 0.01
0 deg Pitch	4.5	-0.36 ± 0.01	-0.45 ± 0.01	-0.50 ± 0.01	-0.57 ± 0.01	-0.65 ± 0.01	-0.69 ± 0.01	-0.82 ± 0.01
30 deg Pitch	4.5	-0.36 ± 0.01	-0.46 ± 0.01	-0.51 ± 0.01	-0.58 ± 0.01	-0.65 ± 0.01	-0.70 ± 0.01	-0.83 ± 0.01
60 deg Pitch	4.5	-0.34 ± 0.01	-0.43 ± 0.01	-0.47 ± 0.01	-0.55 ± 0.01	-0.60 ± 0.01	-0.66 ± 0.01	-0.78 ± 0.01
90 deg Pitch	4.5	-0.31 ± 0.01	-0.41 ± 0.01	-0.44 ± 0.01	-0.51 ± 0.01	-0.57 ± 0.01	-0.62 ± 0.01	-0.73 ± 0.01
Lateral	5.0	-0.31 ± 0.01	-0.40 ± 0.01	-0.42 ± 0.01	-0.50 ± 0.01	-0.55 ± 0.01	-0.60 ± 0.01	-0.70 ± 0.01
0 deg Pitch	5.0	-0.36 ± 0.01	-0.45 ± 0.01	-0.51 ± 0.01	-0.58 ± 0.01	-0.65 ± 0.01	-0.70 ± 0.01	-0.83 ± 0.01
30 deg Pitch	5.0	-0.37 ± 0.01	-0.46 ± 0.01	-0.52 ± 0.01	-0.59 ± 0.01	-0.66 ± 0.01	-0.71 ± 0.01	-0.85 ± 0.01
60 deg Pitch	5.0	-0.33 ± 0.01	-0.44 ± 0.01	-0.49 ± 0.01	-0.56 ± 0.01	-0.63 ± 0.01	-0.69 ± 0.01	-0.81 ± 0.01
90 deg Pitch	5.0	-0.31 ± 0.01	-0.41 ± 0.01	-0.45 ± 0.01	-0.52 ± 0.01	-0.58 ± 0.01	-0.64 ± 0.01	-0.75 ± 0.01
Lateral	5.5	-0.31 ± 0.01	-0.40 ± 0.01	-0.43 ± 0.01	-0.50 ± 0.01	-0.56 ± 0.01	-0.61 ± 0.01	-0.72 ± 0.01
0 deg Pitch	5.5	-0.35 ± 0.01	-0.45 ± 0.01	-0.49 ± 0.01	-0.58 ± 0.00	-0.64 ± 0.01	-0.69 ± 0.01	-0.82 ± 0.01
30 deg Pitch	5.5	-0.36 ± 0.01	-0.46 ± 0.01	-0.51 ± 0.01	-0.58 ± 0.01	-0.66 ± 0.01	-0.71 ± 0.01	-0.85 ± 0.01
60 deg Pitch	5.5	-0.35 ± 0.01	-0.45 ± 0.01	-0.50 ± 0.01	-0.57 ± 0.01	-0.65 ± 0.01	-0.70 ± 0.01	-0.83 ± 0.01
90 deg Pitch	5.5	-0.32 ± 0.01	-0.43 ± 0.01	-0.47 ± 0.01	-0.54 ± 0.01	-0.61 ± 0.01	-0.66 ± 0.01	-0.78 ± 0.01

Table B-6 (Cont'd)

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
0.5 lb Right	4.5 Asymmetric	-0.28 ± 0.01	-0.42 ± 0.01	-0.40 ± 0.01	-0.52 ± 0.01	-0.53 ± 0.01	-0.60 ± 0.01	-0.69 ± 0.01
1.5 lb Right	5.5 Asymmetric	-0.26 ± 0.01	-0.33 ± 0.01	-0.33 ± 0.01	-0.38 ± 0.00	-0.40 ± 0.01	-0.44 ± 0.01	-0.50 ± 0.01
0.5 lb Left	4.5 Asymmetric	-0.35 ± 0.01	-0.44 ± 0.01	-0.49 ± 0.01	-0.57 ± 0.01	-0.63 ± 0.01	-0.68 ± 0.01	-0.81 ± 0.01
1.5 lb Left	5.5 Asymmetric	-0.37 ± 0.01	-0.46 ± 0.01	-0.52 ± 0.01	-0.59 ± 0.01	-0.68 ± 0.01	-0.72 ± 0.01	-0.87 ± 0.01
JHMCS	4.1	-0.22 ± 0.01	-0.33 ± 0.01	-0.31 ± 0.01	-0.39 ± 0.01	-0.39 ± 0.01	-0.44 ± 0.01	-0.50 ± 0.01
NDN	5.4	-0.29 ± 0.01	-0.38 ± 0.01	-0.40 ± 0.01	-0.47 ± 0.01	-0.50 ± 0.01	-0.55 ± 0.01	-0.64 ± 0.01
NT	3.0	-0.26 ± 0.01	-0.35 ± 0.01	-0.35 ± 0.01	-0.42 ± 0.01	-0.44 ± 0.01	-0.49 ± 0.01	-0.57 ± 0.01
AFT	3.3	-0.23 ± 0.01	-0.32 ± 0.01	-0.31 ± 0.01	-0.38 ± 0.01	-0.39 ± 0.01	-0.43 ± 0.01	-0.50 ± 0.01

Table B-7: Mean ± One Standard Deviation HGz (G) for Tactical Lateral and Pitch Configurations and Helmet Systems at 2 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	3.80 ± 0.00	5.71 ± 0.00	7.66 ± 0.00	9.56 ± 0.01	11.47 ± 0.01
Lateral	4.0	3.79 ± 0.00	5.71 ± 0.00	7.64 ± 0.01	9.56 ± 0.01	11.47 ± 0.00
0 deg Pitch	4.0	3.76 ± 0.00	5.67 ± 0.00	7.59 ± 0.00	9.49 ± 0.01	11.37 ± 0.00
30 deg Pitch	4.0	3.73 ± 0.00	5.64 ± 0.00	7.55 ± 0.00	9.42 ± 0.01	11.29 ± 0.00
60 deg Pitch	4.0	3.75 ± 0.00	5.66 ± 0.00	7.56 ± 0.00	9.44 ± 0.01	11.29 ± 0.00
90 deg Pitch	4.0	3.76 ± 0.00	5.69 ± 0.00	7.59 ± 0.00	9.48 ± 0.00	11.35 ± 0.00
Lateral	4.5	3.79 ± 0.00	5.72 ± 0.00	7.64 ± 0.01	9.55 ± 0.01	11.46 ± 0.01
0 deg Pitch	4.5	3.77 ± 0.00	5.69 ± 0.00	7.59 ± 0.00	9.48 ± 0.00	11.34 ± 0.01
30 deg Pitch	4.5	3.79 ± 0.00	5.68 ± 0.00	7.58 ± 0.00	9.46 ± 0.00	11.30 ± 0.00
60 deg Pitch	4.5	3.75 ± 0.00	5.64 ± 0.00	7.52 ± 0.00	9.37 ± 0.01	11.22 ± 0.00
90 deg Pitch	4.5	3.75 ± 0.00	5.67 ± 0.00	7.55 ± 0.00	9.41 ± 0.00	11.26 ± 0.00
Lateral	5.0	3.79 ± 0.00	5.71 ± 0.00	7.62 ± 0.01	9.55 ± 0.01	11.46 ± 0.00
0 deg Pitch	5.0	3.75 ± 0.00	5.68 ± 0.00	7.59 ± 0.00	9.45 ± 0.01	11.32 ± 0.01
30 deg Pitch	5.0	3.78 ± 0.00	5.68 ± 0.00	7.55 ± 0.00	9.40 ± 0.00	11.24 ± 0.00
60 deg Pitch	5.0	3.73 ± 0.00	5.62 ± 0.00	7.49 ± 0.00	9.33 ± 0.00	11.17 ± 0.00
90 deg Pitch	5.0	3.74 ± 0.00	5.64 ± 0.00	7.53 ± 0.00	9.39 ± 0.01	11.22 ± 0.00
Lateral	5.5	3.77 ± 0.00	5.70 ± 0.00	7.62 ± 0.00	9.54 ± 0.01	11.49 ± 0.01
0 deg Pitch	5.5	3.76 ± 0.00	5.66 ± 0.00	7.51 ± 0.00	9.44 ± 0.01	11.30 ± 0.00
30 deg Pitch	5.5	3.76 ± 0.00	5.63 ± 0.00	7.50 ± 0.00	9.35 ± 0.01	11.17 ± 0.00
60 deg Pitch	5.5	3.71 ± 0.00	5.60 ± 0.00	7.45 ± 0.00	9.29 ± 0.01	11.12 ± 0.00
90 deg Pitch	5.5	3.73 ± 0.00	5.61 ± 0.00	7.47 ± 0.00	9.32 ± 0.01	11.15 ± 0.00
0.5 lb Right	4.5 Asymmetric	3.75 ± 0.00	5.67 ± 0.00	7.56 ± 0.01	9.45 ± 0.01	11.29 ± 0.00
1.5 lb Right	5.5 Asymmetric	3.76 ± 0.00	5.66 ± 0.00	7.57 ± 0.00	9.41 ± 0.01	11.30 ± 0.00
0.5 lb Left	4.5 Asymmetric	3.75 ± 0.00	5.65 ± 0.00	7.57 ± 0.00	9.43 ± 0.00	11.31 ± 0.00
1.5 lb Left	5.5 Asymmetric	3.75 ± 0.00	5.66 ± 0.00	7.58 ± 0.00	9.46 ± 0.00	11.33 ± 0.00
JHMCS	4.1	3.76 ± 0.00	5.67 ± 0.00	7.55 ± 0.00	9.40 ± 0.00	11.24 ± 0.00
NDN	5.4	3.75 ± 0.00	5.66 ± 0.00	7.56 ± 0.00	9.48 ± 0.00	11.36 ± 0.00
NT	3.0	3.75 ± 0.00	5.66 ± 0.00	7.57 ± 0.00	9.47 ± 0.01	11.35 ± 0.00
AFT	3.3	3.74 ± 0.00	5.66 ± 0.00	7.56 ± 0.00	9.47 ± 0.01	11.35 ± 0.00

Table B-8: Mean ± One Standard Deviation HGz (G) for Tactical Lateral and Pitch Configurations and Helmet Systems at 6 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	3.79 ± 0.00	5.70 ± 0.00	7.64 ± 0.01	9.55 ± 0.01	11.46 ± 0.01
Lateral	4.0	3.78 ± 0.01	5.71 ± 0.00	7.63 ± 0.01	9.55 ± 0.01	11.46 ± 0.01
0 deg Pitch	4.0	3.75 ± 0.01	5.66 ± 0.01	7.57 ± 0.01	9.48 ± 0.01	11.37 ± 0.01
30 deg Pitch	4.0	3.74 ± 0.01	5.65 ± 0.00	7.54 ± 0.01	9.42 ± 0.01	11.34 ± 0.01
60 deg Pitch	4.0	3.75 ± 0.01	5.66 ± 0.00	7.56 ± 0.00	9.44 ± 0.01	11.29 ± 0.01
90 deg Pitch	4.0	3.76 ± 0.01	5.68 ± 0.00	7.59 ± 0.00	9.48 ± 0.01	11.34 ± 0.01
Lateral	4.5	3.78 ± 0.01	5.71 ± 0.00	7.63 ± 0.00	9.54 ± 0.01	11.46 ± 0.01
0 deg Pitch	4.5	3.76 ± 0.01	5.67 ± 0.00	7.57 ± 0.00	9.46 ± 0.00	11.32 ± 0.01
30 deg Pitch	4.5	3.78 ± 0.01	5.66 ± 0.00	7.56 ± 0.00	9.42 ± 0.01	11.28 ± 0.01
60 deg Pitch	4.5	3.73 ± 0.01	5.64 ± 0.00	7.53 ± 0.00	9.39 ± 0.01	11.22 ± 0.00
90 deg Pitch	4.5	3.74 ± 0.01	5.66 ± 0.00	7.54 ± 0.00	9.42 ± 0.01	11.26 ± 0.01
Lateral	5.0	3.78 ± 0.01	5.71 ± 0.00	7.62 ± 0.00	9.54 ± 0.01	11.46 ± 0.01
0 deg Pitch	5.0	3.76 ± 0.01	5.67 ± 0.00	7.56 ± 0.01	9.45 ± 0.00	11.30 ± 0.01
30 deg Pitch	5.0	3.75 ± 0.01	5.65 ± 0.00	7.52 ± 0.00	9.38 ± 0.01	11.22 ± 0.01
60 deg Pitch	5.0	3.73 ± 0.01	5.62 ± 0.00	7.49 ± 0.00	9.32 ± 0.01	11.17 ± 0.01
90 deg Pitch	5.0	3.74 ± 0.01	5.64 ± 0.00	7.51 ± 0.00	9.35 ± 0.01	11.21 ± 0.01
Lateral	5.5	3.77 ± 0.01	5.70 ± 0.00	7.62 ± 0.00	9.54 ± 0.01	11.46 ± 0.01
0 deg Pitch	5.5	3.75 ± 0.01	5.66 ± 0.00	7.56 ± 0.00	9.42 ± 0.01	11.28 ± 0.01
30 deg Pitch	5.5	3.73 ± 0.01	5.62 ± 0.00	7.48 ± 0.00	9.32 ± 0.00	11.17 ± 0.01
60 deg Pitch	5.5	3.71 ± 0.01	5.58 ± 0.00	7.44 ± 0.00	9.28 ± 0.01	11.12 ± 0.00
90 deg Pitch	5.5	3.70 ± 0.02	5.59 ± 0.00	7.46 ± 0.00	9.30 ± 0.01	11.14 ± 0.01
0.5 lb Right	4.5 Asymmetric	3.74 ± 0.01	5.66 ± 0.00	7.55 ± 0.00	9.43 ± 0.01	11.26 ± 0.01
1.5 lb Right	5.5 Asymmetric	3.74 ± 0.01	5.65 ± 0.00	7.56 ± 0.00	9.44 ± 0.01	11.31 ± 0.01
0.5 lb Left	4.5 Asymmetric	3.73 ± 0.01	5.65 ± 0.01	7.54 ± 0.01	9.42 ± 0.01	11.30 ± 0.01
1.5 lb Left	5.5 Asymmetric	3.74 ± 0.01	5.64 ± 0.00	7.55 ± 0.00	9.43 ± 0.00	11.34 ± 0.01
JHMCS	4.1	3.74 ± 0.00	5.64 ± 0.00	7.53 ± 0.00	9.39 ± 0.01	11.24 ± 0.00
NDN	5.4	3.73 ± 0.01	5.65 ± 0.00	7.56 ± 0.00	9.48 ± 0.00	11.35 ± 0.01
NT	3.0	3.74 ± 0.01	5.64 ± 0.00	7.56 ± 0.01	9.47 ± 0.01	11.35 ± 0.01
AFT	3.3	3.74 ± 0.01	5.64 ± 0.00	7.56 ± 0.01	9.46 ± 0.01	11.34 ± 0.01

Table B-9: HGz (G) (± One Standard Deviation) during +10 Gz SACM at +4, 6, 8, and 10 Gz Plateaus for the Tactical Lateral and Pitch Configurations and Helmet Systems

+8 Gz second plateau value represents the mean of the 2nd and 3rd repetitions. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
Control	3.5	3.84 ± 0.01	3.82 ± 0.01	5.77 ± 0.01	5.75 ± 0.01	7.65 ± 0.01	7.65 ± 0.01	9.53 ± 0.01
Lateral	4.0	3.84 ± 0.01	3.82 ± 0.01	5.76 ± 0.01	5.75 ± 0.01	7.65 ± 0.01	7.65 ± 0.01	9.53 ± 0.01
0 deg Pitch	4.0	3.82 ± 0.00	3.79 ± 0.00	5.73 ± 0.01	5.71 ± 0.01	7.60 ± 0.01	7.59 ± 0.01	9.46 ± 0.01
30 deg Pitch	4.0	3.83 ± 0.00	3.80 ± 0.01	5.75 ± 0.01	5.72 ± 0.01	7.61 ± 0.01	7.60 ± 0.01	9.47 ± 0.01
60 deg Pitch	4.0	3.79 ± 0.01	3.76 ± 0.00	5.70 ± 0.01	5.67 ± 0.01	7.56 ± 0.01	7.55 ± 0.01	9.41 ± 0.01
90 deg Pitch	4.0	3.81 ± 0.00	3.78 ± 0.00	5.73 ± 0.01	5.70 ± 0.01	7.60 ± 0.01	7.59 ± 0.01	9.46 ± 0.01
Lateral	4.5	3.83 ± 0.01	3.81 ± 0.01	5.76 ± 0.01	5.74 ± 0.01	7.64 ± 0.01	7.64 ± 0.01	9.53 ± 0.01
0 deg Pitch	4.5	3.81 ± 0.00	3.78 ± 0.01	5.72 ± 0.01	5.70 ± 0.01	7.59 ± 0.01	7.58 ± 0.01	9.45 ± 0.01
30 deg Pitch	4.5	3.81 ± 0.00	3.77 ± 0.01	5.71 ± 0.01	5.68 ± 0.01	7.57 ± 0.01	7.55 ± 0.01	9.40 ± 0.01
60 deg Pitch	4.5	3.78 ± 0.01	3.75 ± 0.00	5.68 ± 0.01	5.65 ± 0.01	7.52 ± 0.01	7.51 ± 0.01	9.36 ± 0.01
90 deg Pitch	4.5	3.80 ± 0.00	3.77 ± 0.00	5.70 ± 0.01	5.67 ± 0.01	7.55 ± 0.01	7.54 ± 0.01	9.39 ± 0.01
Lateral	5.0	3.83 ± 0.01	3.81 ± 0.01	5.75 ± 0.01	5.74 ± 0.01	7.64 ± 0.01	7.64 ± 0.01	9.53 ± 0.01
0 deg Pitch	5.0	3.81 ± 0.00	3.78 ± 0.00	5.72 ± 0.00	5.69 ± 0.01	7.58 ± 0.01	7.57 ± 0.01	9.44 ± 0.01
30 deg Pitch	5.0	3.80 ± 0.01	3.77 ± 0.00	5.69 ± 0.00	5.67 ± 0.01	7.54 ± 0.01	7.53 ± 0.01	9.36 ± 0.01
60 deg Pitch	5.0	3.77 ± 0.00	3.73 ± 0.00	5.66 ± 0.01	5.62 ± 0.01	7.49 ± 0.01	7.47 ± 0.01	9.31 ± 0.01
90 deg Pitch	5.0	3.79 ± 0.00	3.75 ± 0.00	5.68 ± 0.00	5.65 ± 0.01	7.52 ± 0.01	7.50 ± 0.01	9.34 ± 0.01
Lateral	5.5	3.82 ± 0.01	3.81 ± 0.00	5.75 ± 0.01	5.74 ± 0.01	7.64 ± 0.01	7.63 ± 0.01	9.52 ± 0.01
0 deg Pitch	5.5	3.80 ± 0.00	3.77 ± 0.00	5.71 ± 0.00	5.68 ± 0.01	7.57 ± 0.01	7.56 ± 0.01	9.42 ± 0.01
30 deg Pitch	5.5	3.79 ± 0.00	3.74 ± 0.00	5.67 ± 0.00	5.64 ± 0.01	7.50 ± 0.01	7.49 ± 0.01	9.32 ± 0.01
60 deg Pitch	5.5	3.75 ± 0.00	3.71 ± 0.00	5.63 ± 0.00	5.59 ± 0.01	7.45 ± 0.01	7.44 ± 0.01	9.26 ± 0.01
90 deg Pitch	5.5	3.77 ± 0.00	3.73 ± 0.00	5.65 ± 0.01	5.61 ± 0.01	7.47 ± 0.01	7.46 ± 0.01	9.29 ± 0.01

Table B-9 (Cont'd)

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
0.5 lb Right	4.5 Asymmetric	3.80 ± 0.00	3.77 ± 0.00	5.71 ± 0.01	5.68 ± 0.01	7.56 ± 0.01	7.55 ± 0.01	9.40 ± 0.02
1.5 lb Right	5.5 Asymmetric	3.80 ± 0.01	3.77 ± 0.00	5.71 ± 0.01	5.68 ± 0.01	7.57 ± 0.01	7.56 ± 0.01	9.42 ± 0.01
0.5 lb Left	4.5 Asymmetric	3.79 ± 0.01	3.76 ± 0.01	5.70 ± 0.01	5.67 ± 0.01	7.56 ± 0.01	7.55 ± 0.01	9.40 ± 0.01
1.5 lb Left	5.5 Asymmetric	3.79 ± 0.01	3.75 ± 0.01	5.69 ± 0.01	5.66 ± 0.01	7.55 ± 0.01	7.54 ± 0.01	9.40 ± 0.01
JHMCS	4.1	3.80 ± 0.00	3.76 ± 0.01	5.70 ± 0.01	5.66 ± 0.01	7.54 ± 0.01	7.52 ± 0.01	9.37 ± 0.01
NDN	5.4	3.79 ± 0.00	3.76 ± 0.00	5.70 ± 0.01	5.68 ± 0.01	7.58 ± 0.01	7.57 ± 0.01	9.45 ± 0.01
NT	3.0	3.79 ± 0.01	3.76 ± 0.01	5.70 ± 0.01	5.69 ± 0.01	7.58 ± 0.01	7.57 ± 0.01	9.44 ± 0.01
AFT	3.3	3.79 ± 0.01	3.76 ± 0.01	5.70 ± 0.01	5.69 ± 0.01	7.58 ± 0.01	7.57 ± 0.01	9.44 ± 0.01

Table B-10: Mean ± One Standard Deviation HFxz (lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 2 G/sec Onset Rate

Asymmetric series data represent resultant force including Fy (HFxyz (lb)). NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	33.29 ± 0.12	59.17 ± 0.12	85.49 ± 0.11	111.77 ± 0.13	138.29 ± 0.13
Lateral	4.0	34.97 ± 0.13	61.70 ± 0.11	88.94 ± 0.13	116.25 ± 0.16	143.71 ± 0.13
0 deg Pitch	4.0	35.69 ± 0.11	62.54 ± 0.12	90.04 ± 0.13	117.84 ± 0.15	145.42 ± 0.13
30 deg Pitch	4.0	36.79 ± 0.11	63.99 ± 0.12	92.10 ± 0.14	119.91 ± 0.12	147.88 ± 0.15
60 deg Pitch	4.0	36.64 ± 0.13	64.25 ± 0.16	92.36 ± 0.19	120.40 ± 0.20	148.07 ± 0.16
90 deg Pitch	4.0	36.10 ± 0.11	63.75 ± 0.13	91.86 ± 0.14	120.05 ± 0.13	147.88 ± 0.14
Lateral	4.5	36.85 ± 0.13	64.61 ± 0.12	92.47 ± 0.14	120.71 ± 0.15	148.88 ± 0.13
0 deg Pitch	4.5	37.67 ± 0.11	65.76 ± 0.12	94.11 ± 0.14	122.92 ± 0.13	151.82 ± 0.14
30 deg Pitch	4.5	40.08 ± 0.08	68.72 ± 0.14	97.68 ± 0.12	126.66 ± 0.15	155.17 ± 0.14
60 deg Pitch	4.5	39.92 ± 0.11	68.90 ± 0.16	98.05 ± 0.19	126.80 ± 0.21	155.70 ± 0.18
90 deg Pitch	4.5	39.10 ± 0.08	68.45 ± 0.10	97.64 ± 0.13	125.95 ± 0.12	154.74 ± 0.13
Lateral	5.0	38.69 ± 0.11	67.25 ± 0.12	96.03 ± 0.14	125.14 ± 0.14	154.24 ± 0.14
0 deg Pitch	5.0	39.62 ± 0.11	68.95 ± 0.13	98.58 ± 0.12	128.31 ± 0.13	158.20 ± 0.12
30 deg Pitch	5.0	42.22 ± 0.13	72.29 ± 0.12	102.34 ± 0.12	132.02 ± 0.13	161.68 ± 0.12
60 deg Pitch	5.0	42.68 ± 0.16	73.15 ± 0.16	103.24 ± 0.19	132.84 ± 0.20	162.45 ± 0.17
90 deg Pitch	5.0	42.13 ± 0.13	72.69 ± 0.11	103.09 ± 0.14	132.95 ± 0.19	162.28 ± 0.15
Lateral	5.5	40.50 ± 0.08	70.18 ± 0.13	99.92 ± 0.13	129.96 ± 0.14	160.71 ± 0.14
0 deg Pitch	5.5	41.89 ± 0.10	71.92 ± 0.12	102.05 ± 0.13	133.76 ± 0.13	164.61 ± 0.12
30 deg Pitch	5.5	44.39 ± 0.10	75.50 ± 0.12	106.75 ± 0.13	137.53 ± 0.16	167.71 ± 0.15
60 deg Pitch	5.5	45.73 ± 0.15	77.36 ± 0.16	108.29 ± 0.20	138.68 ± 0.23	169.07 ± 0.19
90 deg Pitch	5.5	45.48 ± 0.12	77.04 ± 0.13	107.86 ± 0.16	138.41 ± 0.20	168.68 ± 0.15
0.5 lb Right	4.5 Asymmetric	39.96 ± 0.11	68.58 ± 0.13	97.66 ± 0.17	127.00 ± 0.17	155.76 ± 0.14
1.5 lb Right	5.5 Asymmetric	44.27 ± 0.09	74.86 ± 0.11	105.99 ± 0.13	136.41 ± 0.15	167.97 ± 0.12
0.5 lb Left	4.5 Asymmetric	40.18 ± 0.12	68.26 ± 0.11	97.29 ± 0.14	125.83 ± 0.13	154.96 ± 0.13
1.5 lb Left	5.5 Asymmetric	44.43 ± 0.12	74.11 ± 0.12	104.62 ± 0.13	134.95 ± 0.15	165.53 ± 0.14
JHMCS	4.1	37.78 ± 0.11	67.05 ± 0.12	95.42 ± 0.13	123.57 ± 0.15	152.23 ± 0.13
NDN	5.4	40.34 ± 0.12	69.88 ± 0.10	99.70 ± 0.12	129.93 ± 0.13	160.13 ± 0.13
NT	3.0	34.11 ± 0.12	60.47 ± 0.09	87.31 ± 0.12	114.01 ± 0.15	140.82 ± 0.13
AFT	3.3	32.64 ± 0.10	58.54 ± 0.12	84.57 ± 0.13	110.66 ± 0.15	136.85 ± 0.14

Table B-11: Mean ± One Standard Deviation HFxz (lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 6 G/sec Onset Rate

Asymmetric series data represent resultant force including Fy (HFxyz (lb)). NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	33.17 ± 0.13	59.19 ± 0.11	85.79 ± 0.14	112.17 ± 0.15	138.90 ± 0.15
Lateral	4.0	34.80 ± 0.22	62.08 ± 0.13	89.34 ± 0.14	116.63 ± 0.15	144.41 ± 0.16
0 deg Pitch	4.0	35.81 ± 0.28	63.03 ± 0.13	90.59 ± 0.14	118.15 ± 0.17	146.05 ± 0.15
30 deg Pitch	4.0	37.29 ± 0.22	64.98 ± 0.12	92.97 ± 0.13	120.43 ± 0.13	148.12 ± 0.25
60 deg Pitch	4.0	37.09 ± 0.33	64.88 ± 0.20	92.72 ± 0.19	120.69 ± 0.18	148.73 ± 0.28
90 deg Pitch	4.0	36.52 ± 0.23	64.49 ± 0.13	92.30 ± 0.14	120.36 ± 0.16	148.11 ± 0.15
Lateral	4.5	36.73 ± 0.22	64.81 ± 0.14	92.88 ± 0.14	121.03 ± 0.16	149.64 ± 0.15
0 deg Pitch	4.5	37.98 ± 0.21	66.39 ± 0.12	94.90 ± 0.14	123.25 ± 0.14	151.91 ± 0.14
30 deg Pitch	4.5	40.51 ± 0.20	68.91 ± 0.13	97.90 ± 0.12	126.62 ± 0.15	155.51 ± 0.17
60 deg Pitch	4.5	40.16 ± 0.40	69.36 ± 0.20	98.77 ± 0.17	127.55 ± 0.21	156.03 ± 0.18
90 deg Pitch	4.5	39.25 ± 0.19	68.68 ± 0.14	97.79 ± 0.10	126.74 ± 0.14	155.22 ± 0.16
Lateral	5.0	38.70 ± 0.23	67.56 ± 0.12	96.45 ± 0.14	125.59 ± 0.13	154.81 ± 0.15
0 deg Pitch	5.0	40.23 ± 0.28	69.61 ± 0.13	99.18 ± 0.14	128.95 ± 0.15	158.29 ± 0.15
30 deg Pitch	5.0	42.34 ± 0.23	72.30 ± 0.13	102.42 ± 0.13	132.24 ± 0.16	162.06 ± 0.17
60 deg Pitch	5.0	43.12 ± 0.35	73.52 ± 0.17	103.62 ± 0.18	133.26 ± 0.21	163.16 ± 0.24
90 deg Pitch	5.0	42.56 ± 0.19	73.11 ± 0.13	103.22 ± 0.15	132.85 ± 0.20	162.41 ± 0.17
Lateral	5.5	40.60 ± 0.28	70.61 ± 0.13	100.43 ± 0.13	130.58 ± 0.13	160.70 ± 0.15
0 deg Pitch	5.5	42.39 ± 0.24	72.92 ± 0.12	103.60 ± 0.13	134.16 ± 0.15	165.63 ± 0.19
30 deg Pitch	5.5	44.69 ± 0.23	75.91 ± 0.12	106.97 ± 0.14	137.58 ± 0.14	168.35 ± 0.20
60 deg Pitch	5.5	46.15 ± 0.33	77.34 ± 0.18	108.62 ± 0.23	139.12 ± 0.28	169.39 ± 0.21
90 deg Pitch	5.5	45.14 ± 0.41	76.96 ± 0.14	108.20 ± 0.16	138.60 ± 0.22	169.04 ± 0.17
0.5 lb Right	4.5 Asymmetric	40.50 ± 0.39	69.15 ± 0.11	98.01 ± 0.14	127.02 ± 0.17	155.40 ± 0.15
1.5 lb Right	5.5 Asymmetric	44.58 ± 0.22	75.39 ± 0.10	106.16 ± 0.12	137.38 ± 0.17	168.52 ± 0.19
0.5 lb Left	4.5 Asymmetric	40.39 ± 0.27	68.89 ± 0.15	97.50 ± 0.14	126.05 ± 0.14	155.27 ± 0.21
1.5 lb Left	5.5 Asymmetric	44.74 ± 0.22	74.85 ± 0.13	105.01 ± 0.13	134.87 ± 0.13	166.08 ± 0.16
JHMCS	4.1	36.75 ± 0.15	66.04 ± 0.11	94.84 ± 0.14	123.34 ± 0.16	151.91 ± 0.18
NDN	5.4	40.44 ± 0.26	70.58 ± 0.13	100.69 ± 0.10	130.77 ± 0.13	160.78 ± 0.15
NT	3.0	33.78 ± 0.23	60.62 ± 0.12	87.75 ± 0.15	114.51 ± 0.14	141.13 ± 0.15
AFT	3.3	32.58 ± 0.25	58.49 ± 0.13	84.91 ± 0.14	111.09 ± 0.15	137.41 ± 0.13

Table B-12: HFxz (lb) (± One Standard Deviation) during +10 Gz SACM at +4, 6, 8, and 10 Gz Plateaus for the Tactical Lateral and Pitch Configurations and Helmet Systems

Asymmetric series data represent resultant force including Fy (HFxyz (lb)). +8 Gz second plateau value represents the mean of the 2nd and 3rd repetitions. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
Control	3.5	33.75 ± 0.14	34.25 ± 0.14	59.91 ± 0.15	60.76 ± 0.14	85.96 ± 0.20	86.06 ± 0.21	112.28 ± 0.17
Lateral	4.0	35.61 ± 0.15	36.02 ± 0.15	62.74 ± 0.15	63.60 ± 0.14	89.71 ± 0.23	89.80 ± 0.22	116.88 ± 0.21
0 deg Pitch	4.0	36.55 ± 0.12	37.46 ± 0.13	63.96 ± 0.12	64.91 ± 0.15	91.09 ± 0.19	91.28 ± 0.20	118.36 ± 0.17
30 deg Pitch	4.0	38.30 ± 0.13	38.88 ± 0.14	65.88 ± 0.15	66.69 ± 0.15	93.13 ± 0.20	93.35 ± 0.19	120.63 ± 0.18
60 deg Pitch	4.0	37.58 ± 0.14	38.63 ± 0.14	65.57 ± 0.13	66.62 ± 0.17	93.14 ± 0.22	93.38 ± 0.22	120.65 ± 0.21
90 deg Pitch	4.0	36.84 ± 0.09	38.09 ± 0.12	64.91 ± 0.13	66.16 ± 0.18	92.55 ± 0.21	92.92 ± 0.21	120.14 ± 0.21
Lateral	4.5	37.43 ± 0.14	37.88 ± 0.14	65.47 ± 0.13	66.30 ± 0.16	93.24 ± 0.19	93.33 ± 0.22	121.14 ± 0.21
0 deg Pitch	4.5	38.62 ± 0.14	39.63 ± 0.16	67.05 ± 0.13	68.13 ± 0.18	95.16 ± 0.18	95.46 ± 0.18	123.50 ± 0.20
30 deg Pitch	4.5	40.44 ± 0.15	41.46 ± 0.15	69.43 ± 0.17	70.39 ± 0.18	97.92 ± 0.21	98.15 ± 0.19	126.54 ± 0.19
60 deg Pitch	4.5	40.67 ± 0.15	41.74 ± 0.14	69.83 ± 0.17	70.96 ± 0.22	98.61 ± 0.22	98.80 ± 0.22	127.12 ± 0.23
90 deg Pitch	4.5	39.89 ± 0.13	41.04 ± 0.15	69.21 ± 0.14	70.20 ± 0.19	97.92 ± 0.20	98.12 ± 0.22	126.49 ± 0.22
Lateral	5.0	39.19 ± 0.13	39.64 ± 0.15	68.23 ± 0.14	68.85 ± 0.17	96.80 ± 0.21	96.88 ± 0.20	125.60 ± 0.19
0 deg Pitch	5.0	40.74 ± 0.11	41.94 ± 0.15	70.30 ± 0.15	71.47 ± 0.16	99.44 ± 0.19	99.75 ± 0.20	128.70 ± 0.19
30 deg Pitch	5.0	42.81 ± 0.15	43.78 ± 0.14	73.03 ± 0.14	73.77 ± 0.17	102.58 ± 0.20	102.64 ± 0.20	131.99 ± 0.21
60 deg Pitch	5.0	43.79 ± 0.14	45.03 ± 0.17	73.34 ± 0.21	75.15 ± 0.19	103.92 ± 0.25	104.24 ± 0.20	133.29 ± 0.21
90 deg Pitch	5.0	43.16 ± 0.10	44.37 ± 0.12	73.66 ± 0.14	74.50 ± 0.20	103.32 ± 0.23	103.40 ± 0.21	132.57 ± 0.24
Lateral	5.5	41.30 ± 0.15	41.74 ± 0.15	71.14 ± 0.14	71.83 ± 0.18	100.69 ± 0.24	100.80 ± 0.20	130.53 ± 0.19
0 deg Pitch	5.5	43.37 ± 0.14	44.66 ± 0.15	74.03 ± 0.14	75.29 ± 0.15	104.19 ± 0.18	104.63 ± 0.19	134.61 ± 0.20
30 deg Pitch	5.5	45.10 ± 0.14	46.38 ± 0.16	76.37 ± 0.14	77.39 ± 0.17	106.97 ± 0.21	107.17 ± 0.22	137.35 ± 0.22
60 deg Pitch	5.5	46.57 ± 0.12	47.78 ± 0.15	78.28 ± 0.18	78.77 ± 0.18	108.63 ± 0.25	108.67 ± 0.23	138.69 ± 0.27
90 deg Pitch	5.5	46.14 ± 0.14	47.38 ± 0.16	77.73 ± 0.19	78.36 ± 0.35	108.25 ± 0.26	108.24 ± 0.31	138.29 ± 0.27

Table B-12 (Cont'd)

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
0.5 lb Right	4.5 Asymmetric	40.91 ± 0.14	41.60 ± 0.13	69.72 ± 0.19	70.48 ± 0.22	98.24 ± 0.21	98.58 ± 0.18	126.75 ± 0.31
1.5 lb Right	5.5 Asymmetric	45.09 ± 0.18	45.91 ± 0.13	76.06 ± 0.17	76.95 ± 0.17	106.78 ± 0.27	107.06 ± 0.24	137.45 ± 0.31
0.5 lb Left	4.5 Asymmetric	41.15 ± 0.13	42.11 ± 0.18	69.76 ± 0.12	70.81 ± 0.19	98.11 ± 0.18	98.41 ± 0.20	126.44 ± 0.26
1.5 lb Left	5.5 Asymmetric	45.74 ± 0.14	46.76 ± 0.17	76.14 ± 0.13	77.28 ± 0.26	106.43 ± 0.24	106.75 ± 0.25	136.72 ± 0.24
JHMCS	4.1	37.40 ± 0.13	38.57 ± 0.14	66.29 ± 0.19	67.33 ± 0.16	94.85 ± 0.20	95.07 ± 0.24	123.09 ± 0.24
NDN	5.4	41.25 ± 0.12	42.19 ± 0.12	71.23 ± 0.13	72.44 ± 0.15	100.67 ± 0.17	101.24 ± 0.17	130.52 ± 0.18
NT	3.0	35.04 ± 0.11	36.06 ± 0.15	61.93 ± 0.15	63.25 ± 0.16	88.51 ± 0.24	88.70 ± 0.24	115.10 ± 0.23
AFT	3.3	33.27 ± 0.12	34.19 ± 0.16	59.43 ± 0.15	60.82 ± 0.16	85.54 ± 0.24	85.74 ± 0.25	111.74 ± 0.21

Table B-13: Mean ± One Standard Deviation NFxz (lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 2 G/sec Onset Rate

Asymmetric series data represent resultant force including Fy (NFxyz (lb)). NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	59.56 ± 0.14	100.41 ± 0.14	141.79 ± 0.14	182.58 ± 0.19	223.54 ± 0.18
Lateral	4.0	62.35 ± 0.16	104.23 ± 0.15	146.37 ± 0.17	188.39 ± 0.20	230.35 ± 0.18
0 deg Pitch	4.0	65.44 ± 0.20	106.95 ± 0.16	149.00 ± 0.24	190.98 ± 0.19	232.48 ± 0.21
30 deg Pitch	4.0	65.65 ± 0.15	107.28 ± 0.18	149.54 ± 0.18	191.11 ± 0.18	233.15 ± 0.16
60 deg Pitch	4.0	64.92 ± 0.13	106.94 ± 0.16	148.98 ± 0.19	190.96 ± 0.20	232.62 ± 0.16
90 deg Pitch	4.0	65.14 ± 0.15	107.21 ± 0.16	149.28 ± 0.21	191.51 ± 0.17	233.41 ± 0.20
Lateral	4.5	65.34 ± 0.16	108.28 ± 0.18	151.05 ± 0.18	193.95 ± 0.19	236.57 ± 0.17
0 deg Pitch	4.5	67.73 ± 0.18	110.45 ± 0.18	153.02 ± 0.22	195.55 ± 0.19	238.26 ± 0.21
30 deg Pitch	4.5	66.82 ± 0.12	109.27 ± 0.18	152.40 ± 0.21	195.29 ± 0.21	237.78 ± 0.24
60 deg Pitch	4.5	67.02 ± 0.11	109.85 ± 0.16	152.80 ± 0.19	195.41 ± 0.21	238.47 ± 0.18
90 deg Pitch	4.5	67.70 ± 0.16	110.78 ± 0.11	153.80 ± 0.20	195.85 ± 0.17	238.88 ± 0.18
Lateral	5.0	68.01 ± 0.16	111.68 ± 0.15	155.39 ± 0.19	199.37 ± 0.18	243.09 ± 0.18
0 deg Pitch	5.0	69.53 ± 0.13	113.61 ± 0.23	157.14 ± 0.19	200.49 ± 0.18	244.25 ± 0.15
30 deg Pitch	5.0	69.08 ± 0.17	113.04 ± 0.20	156.73 ± 0.21	200.18 ± 0.25	243.91 ± 0.20
60 deg Pitch	5.0	69.07 ± 0.16	113.21 ± 0.16	157.02 ± 0.19	200.53 ± 0.20	244.39 ± 0.17
90 deg Pitch	5.0	68.61 ± 0.17	112.71 ± 0.13	156.91 ± 0.18	200.74 ± 0.24	244.24 ± 0.19
Lateral	5.5	70.05 ± 0.12	114.84 ± 0.15	159.52 ± 0.23	204.34 ± 0.18	249.75 ± 0.18
0 deg Pitch	5.5	71.78 ± 0.22	116.05 ± 0.17	159.58 ± 0.19	205.37 ± 0.17	250.04 ± 0.19
30 deg Pitch	5.5	71.13 ± 0.17	115.68 ± 0.23	160.62 ± 0.20	205.27 ± 0.25	249.50 ± 0.24
60 deg Pitch	5.5	70.87 ± 0.15	116.00 ± 0.16	160.82 ± 0.20	205.23 ± 0.23	249.85 ± 0.19
90 deg Pitch	5.5	70.64 ± 0.15	115.72 ± 0.17	160.43 ± 0.21	205.07 ± 0.26	249.62 ± 0.18
0.5 lb Right	4.5 Asymmetric	68.64 ± 0.19	111.85 ± 0.21	154.74 ± 0.21	198.18 ± 0.23	240.92 ± 0.24
1.5 lb Right	5.5 Asymmetric	73.38 ± 0.16	117.99 ± 0.17	163.30 ± 0.23	207.25 ± 0.23	252.93 ± 0.18
0.5 lb Left	4.5 Asymmetric	69.58 ± 0.21	112.30 ± 0.14	155.52 ± 0.23	198.06 ± 0.18	241.45 ± 0.19
1.5 lb Left	5.5 Asymmetric	73.62 ± 0.15	118.04 ± 0.18	163.17 ± 0.19	207.60 ± 0.19	252.20 ± 0.20
JHMCS	4.1	63.95 ± 0.26	107.02 ± 0.23	149.17 ± 0.26	191.33 ± 0.28	234.14 ± 0.21
NDN	5.4	70.83 ± 0.18	114.90 ± 0.14	159.14 ± 0.24	203.66 ± 0.19	247.83 ± 0.21
NT	3.0	63.51 ± 0.14	104.36 ± 0.17	145.78 ± 0.15	186.73 ± 0.28	227.93 ± 0.17
AFT	3.3	64.43 ± 0.14	105.09 ± 0.18	145.67 ± 0.18	186.27 ± 0.21	226.62 ± 0.16

Table B-14: Mean ± One Standard Deviation NFxz (lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 6 G/sec Onset Rate

Asymmetric series data represent resultant force including Fy (NFxyz (lb)). NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	59.52 ± 0.17	100.23 ± 0.16	141.78 ± 0.20	182.51 ± 0.20	223.66 ± 0.18
Lateral	4.0	62.27 ± 0.33	104.63 ± 0.18	146.54 ± 0.19	188.64 ± 0.20	230.69 ± 0.19
0 deg Pitch	4.0	65.29 ± 0.41	107.01 ± 0.23	149.01 ± 0.23	190.86 ± 0.20	232.88 ± 0.22
30 deg Pitch	4.0	65.79 ± 0.33	107.84 ± 0.15	149.76 ± 0.17	191.41 ± 0.18	232.36 ± 0.29
60 deg Pitch	4.0	65.07 ± 0.33	107.05 ± 0.20	149.12 ± 0.19	191.15 ± 0.18	232.55 ± 0.28
90 deg Pitch	4.0	65.31 ± 0.35	107.58 ± 0.17	149.72 ± 0.17	191.91 ± 0.21	233.68 ± 0.18
Lateral	4.5	65.41 ± 0.32	108.38 ± 0.18	151.23 ± 0.15	194.09 ± 0.20	237.03 ± 0.19
0 deg Pitch	4.5	67.45 ± 0.33	110.41 ± 0.15	153.01 ± 0.24	195.49 ± 0.22	238.05 ± 0.19
30 deg Pitch	4.5	66.77 ± 0.34	109.38 ± 0.25	152.55 ± 0.16	195.04 ± 0.20	238.02 ± 0.20
60 deg Pitch	4.5	66.89 ± 0.40	110.03 ± 0.20	153.41 ± 0.17	196.21 ± 0.21	238.71 ± 0.18
90 deg Pitch	4.5	67.39 ± 0.29	110.78 ± 0.20	153.80 ± 0.13	196.77 ± 0.19	239.27 ± 0.22
Lateral	5.0	68.05 ± 0.35	111.98 ± 0.15	155.69 ± 0.18	199.52 ± 0.18	243.34 ± 0.18
0 deg Pitch	5.0	69.71 ± 0.40	113.45 ± 0.17	157.11 ± 0.19	200.88 ± 0.23	244.03 ± 0.21
30 deg Pitch	5.0	68.89 ± 0.37	112.70 ± 0.22	156.57 ± 0.16	200.34 ± 0.22	244.16 ± 0.28
60 deg Pitch	5.0	69.30 ± 0.35	113.36 ± 0.17	157.39 ± 0.18	200.97 ± 0.21	244.44 ± 0.24
90 deg Pitch	5.0	68.48 ± 0.31	112.71 ± 0.18	156.76 ± 0.19	200.31 ± 0.25	244.09 ± 0.22
Lateral	5.5	70.23 ± 0.42	115.18 ± 0.20	159.87 ± 0.19	204.60 ± 0.19	249.23 ± 0.20
0 deg Pitch	5.5	71.64 ± 0.34	116.51 ± 0.18	161.20 ± 0.19	205.56 ± 0.21	250.23 ± 0.24
30 deg Pitch	5.5	71.08 ± 0.36	115.96 ± 0.17	160.75 ± 0.20	205.10 ± 0.22	250.06 ± 0.28
60 deg Pitch	5.5	71.17 ± 0.33	115.92 ± 0.18	161.12 ± 0.23	205.55 ± 0.28	250.29 ± 0.21
90 deg Pitch	5.5	70.10 ± 0.67	115.50 ± 0.20	160.70 ± 0.22	205.19 ± 0.28	249.92 ± 0.20
0.5 lb Right	4.5 Asymmetric	68.98 ± 0.53	112.03 ± 0.19	154.98 ± 0.19	198.18 ± 0.24	240.62 ± 0.21
1.5 lb Right	5.5 Asymmetric	73.10 ± 0.40	118.31 ± 0.18	163.35 ± 0.16	208.50 ± 0.24	253.18 ± 0.25
0.5 lb Left	4.5 Asymmetric	69.41 ± 0.47	112.48 ± 0.26	155.44 ± 0.19	198.20 ± 0.20	241.46 ± 0.24
1.5 lb Left	5.5 Asymmetric	73.56 ± 0.40	118.25 ± 0.22	163.11 ± 0.22	207.30 ± 0.20	252.57 ± 0.22
JHMCS	4.1	64.02 ± 0.23	107.06 ± 0.21	150.03 ± 0.23	192.37 ± 0.26	234.96 ± 0.24
NDN	5.4	70.87 ± 0.39	115.51 ± 0.18	160.05 ± 0.21	204.38 ± 0.17	248.44 ± 0.23
NT	3.0	63.64 ± 0.28	104.88 ± 0.22	146.44 ± 0.21	187.55 ± 0.22	228.50 ± 0.21
AFT	3.3	64.82 ± 0.33	105.22 ± 0.20	146.21 ± 0.20	186.73 ± 0.27	227.24 ± 0.18

Table B-15: NFxz (lb) (± One Standard Deviation) during +10 Gz SACM at +4, 6, 8, and 10 Gz Plateaus for the Tactical Lateral and Pitch Configurations and Helmet Systems

Asymmetric series data represent resultant force including Fy (NFxyz (lb)). +8 Gz second plateau value represents the mean of the 2nd and 3rd repetitions. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
Control	3.5	60.92 ± 0.17	61.00 ± 0.19	101.97 ± 0.20	102.31 ± 0.21	142.42 ± 0.27	142.59 ± 0.27	182.88 ± 0.21
Lateral	4.0	64.07 ± 0.18	64.18 ± 0.20	106.14 ± 0.22	106.48 ± 0.18	147.57 ± 0.25	147.75 ± 0.26	188.95 ± 0.27
0 deg Pitch	4.0	66.84 ± 0.21	66.71 ± 0.17	108.60 ± 0.21	108.86 ± 0.19	149.87 ± 0.24	150.01 ± 0.27	191.11 ± 0.21
30 deg Pitch	4.0	66.20 ± 0.17	65.99 ± 0.15	108.07 ± 0.20	108.27 ± 0.18	149.40 ± 0.24	149.51 ± 0.24	190.70 ± 0.26
60 deg Pitch	4.0	65.76 ± 0.16	65.72 ± 0.17	107.81 ± 0.17	108.06 ± 0.21	149.31 ± 0.27	149.41 ± 0.26	190.66 ± 0.27
90 deg Pitch	4.0	66.75 ± 0.15	66.91 ± 0.15	108.84 ± 0.19	109.32 ± 0.20	150.40 ± 0.26	150.62 ± 0.25	191.93 ± 0.27
Lateral	4.5	66.85 ± 0.19	66.95 ± 0.19	109.80 ± 0.18	110.16 ± 0.18	152.11 ± 0.24	152.28 ± 0.28	194.44 ± 0.25
0 deg Pitch	4.5	68.82 ± 0.17	68.80 ± 0.19	111.63 ± 0.17	111.88 ± 0.21	153.75 ± 0.25	153.93 ± 0.25	195.93 ± 0.26
30 deg Pitch	4.5	67.91 ± 0.20	67.88 ± 0.19	110.78 ± 0.22	111.06 ± 0.24	153.05 ± 0.24	153.23 ± 0.23	195.39 ± 0.27
60 deg Pitch	4.5	68.09 ± 0.19	68.14 ± 0.15	111.10 ± 0.20	111.49 ± 0.27	153.52 ± 0.24	153.70 ± 0.25	195.94 ± 0.28
90 deg Pitch	4.5	68.91 ± 0.14	68.88 ± 0.18	111.97 ± 0.17	112.20 ± 0.21	154.32 ± 0.25	154.48 ± 0.30	196.66 ± 0.28
Lateral	5.0	69.26 ± 0.19	69.41 ± 0.20	113.26 ± 0.18	113.60 ± 0.20	156.49 ± 0.27	156.63 ± 0.26	199.71 ± 0.25
0 deg Pitch	5.0	70.97 ± 0.17	70.96 ± 0.21	114.68 ± 0.19	114.98 ± 0.20	157.81 ± 0.24	157.92 ± 0.27	200.83 ± 0.23
30 deg Pitch	5.0	70.23 ± 0.17	70.13 ± 0.22	114.06 ± 0.18	114.27 ± 0.23	157.30 ± 0.23	157.40 ± 0.28	200.42 ± 0.31
60 deg Pitch	5.0	69.95 ± 0.18	69.96 ± 0.22	114.00 ± 0.24	114.26 ± 0.24	157.33 ± 0.28	157.50 ± 0.28	200.52 ± 0.33
90 deg Pitch	5.0	69.75 ± 0.13	69.76 ± 0.15	113.85 ± 0.17	114.05 ± 0.25	157.19 ± 0.28	157.28 ± 0.28	200.35 ± 0.30
Lateral	5.5	71.70 ± 0.18	71.77 ± 0.22	116.50 ± 0.21	116.80 ± 0.21	160.60 ± 0.29	160.76 ± 0.26	204.73 ± 0.23
0 deg Pitch	5.5	72.83 ± 0.22	72.76 ± 0.22	117.56 ± 0.27	117.87 ± 0.24	161.53 ± 0.22	161.72 ± 0.23	205.65 ± 0.30
30 deg Pitch	5.5	72.44 ± 0.17	72.43 ± 0.27	117.27 ± 0.21	117.50 ± 0.21	161.30 ± 0.24	161.55 ± 0.26	205.38 ± 0.29
60 deg Pitch	5.5	72.48 ± 0.15	72.50 ± 0.19	117.51 ± 0.21	117.72 ± 0.20	161.58 ± 0.31	161.79 ± 0.27	205.61 ± 0.34
90 deg Pitch	5.5	71.96 ± 0.17	72.05 ± 0.21	117.06 ± 0.24	117.27 ± 0.28	161.25 ± 0.31	161.41 ± 0.36	205.37 ± 0.34

Table B-15 (Cont'd)

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
0.5 lb Right	4.5 Asymmetric	84.73 ± 0.18	85.79 ± 0.20	123.93 ± 0.27	124.79 ± 0.22	164.51 ± 0.27	165.15 ± 0.24	205.93 ± 0.41
1.5 lb Right	5.5 Asymmetric	88.40 ± 0.23	89.42 ± 0.22	129.76 ± 0.30	130.60 ± 0.20	172.43 ± 0.36	172.86 ± 0.30	215.88 ± 0.32
0.5 lb Left	4.5 Asymmetric	85.11 ± 0.22	86.48 ± 0.23	124.43 ± 0.17	125.46 ± 0.20	165.01 ± 0.22	165.56 ± 0.26	206.43 ± 0.34
1.5 lb Left	5.5 Asymmetric	88.74 ± 0.18	90.07 ± 0.20	130.05 ± 0.18	131.10 ± 0.29	172.44 ± 0.27	173.04 ± 0.26	215.72 ± 0.35
JHMCS	4.1	66.35 ± 0.18	66.35 ± 0.24	108.95 ± 0.27	109.18 ± 0.25	150.78 ± 0.27	150.98 ± 0.33	192.58 ± 0.30
NDN	5.4	72.64 ± 0.21	72.81 ± 0.15	116.95 ± 0.17	117.49 ± 0.26	160.65 ± 0.24	161.04 ± 0.26	204.51 ± 0.29
NT	3.0	65.69 ± 0.20	66.05 ± 0.23	107.01 ± 0.20	107.68 ± 0.22	147.68 ± 0.38	147.86 ± 0.34	188.23 ± 0.30
AFT	3.3	66.42 ± 0.16	66.71 ± 0.22	107.09 ± 0.21	107.76 ± 0.18	147.23 ± 0.32	147.45 ± 0.34	187.41 ± 0.26

Table B-16: Mean ± One Standard Deviation HMy (in.-lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 2 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	4.75 ± 0.31	7.32 ± 0.34	10.91 ± 0.52	15.29 ± 0.75	20.72 ± 0.53
Lateral	4.0	3.94 ± 0.32	6.50 ± 0.28	9.62 ± 0.48	13.68 ± 0.72	18.70 ± 0.43
0 deg Pitch	4.0	8.50 ± 0.21	13.60 ± 0.33	19.77 ± 0.48	26.72 ± 0.75	35.36 ± 0.41
30 deg Pitch	4.0	12.99 ± 0.27	20.97 ± 0.36	29.83 ± 0.50	40.63 ± 0.79	53.76 ± 0.55
60 deg Pitch	4.0	17.12 ± 0.27	26.69 ± 0.41	37.30 ± 0.64	50.46 ± 0.77	65.62 ± 0.47
90 deg Pitch	4.0	17.03 ± 0.33	26.45 ± 0.44	36.72 ± 0.60	48.43 ± 0.55	62.99 ± 0.45
Lateral	4.5	3.16 ± 0.28	5.51 ± 0.34	8.40 ± 0.51	12.01 ± 0.66	16.32 ± 0.48
0 deg Pitch	4.5	10.11 ± 0.29	16.69 ± 0.38	24.36 ± 0.62	33.45 ± 0.60	45.05 ± 0.37
30 deg Pitch	4.5	20.32 ± 0.32	32.42 ± 0.43	46.50 ± 0.52	63.94 ± 0.75	83.36 ± 0.53
60 deg Pitch	4.5	26.78 ± 0.39	42.28 ± 0.43	60.80 ± 0.67	81.70 ± 1.03	105.00 ± 0.72
90 deg Pitch	4.5	27.50 ± 0.37	43.19 ± 0.36	61.16 ± 0.65	83.21 ± 0.68	105.55 ± 0.56
Lateral	5.0	1.58 ± 0.26	3.00 ± 0.29	5.14 ± 0.58	7.97 ± 0.55	11.66 ± 0.44
0 deg Pitch	5.0	11.88 ± 0.28	20.22 ± 0.56	29.69 ± 0.66	41.55 ± 0.53	56.76 ± 0.42
30 deg Pitch	5.0	27.35 ± 0.27	44.29 ± 0.44	64.91 ± 0.58	87.91 ± 0.68	114.02 ± 0.49
60 deg Pitch	5.0	37.58 ± 0.35	60.59 ± 0.49	86.67 ± 0.60	114.92 ± 0.88	145.34 ± 0.53
90 deg Pitch	5.0	39.79 ± 0.39	62.65 ± 0.49	88.24 ± 0.70	115.94 ± 1.22	144.96 ± 0.56
Lateral	5.5	2.07 ± 0.23	3.76 ± 0.32	6.14 ± 0.53	9.18 ± 0.61	13.24 ± 0.44
0 deg Pitch	5.5	14.52 ± 0.33	23.97 ± 0.44	34.91 ± 0.61	50.43 ± 0.63	69.35 ± 0.52
30 deg Pitch	5.5	35.13 ± 0.32	57.89 ± 0.42	84.47 ± 0.70	114.27 ± 0.86	146.04 ± 0.65
60 deg Pitch	5.5	49.36 ± 0.41	79.91 ± 0.52	113.88 ± 0.83	149.48 ± 0.99	186.88 ± 0.57
90 deg Pitch	5.5	51.60 ± 0.37	81.77 ± 0.49	114.39 ± 0.82	148.29 ± 0.95	184.01 ± 0.51
0.5 lb Right	4.5 Asymmetric	15.96 ± 0.27	26.02 ± 0.35	36.57 ± 0.64	49.53 ± 0.75	64.20 ± 0.46
1.5 lb Right	5.5 Asymmetric	17.30 ± 0.27	27.44 ± 0.28	39.05 ± 0.54	51.72 ± 0.63	67.31 ± 0.36
0.5 lb Left	4.5 Asymmetric	16.51 ± 0.24	26.38 ± 0.33	37.04 ± 0.53	49.06 ± 0.48	62.93 ± 0.46
1.5 lb Left	5.5 Asymmetric	17.58 ± 0.32	28.32 ± 0.39	39.44 ± 0.49	51.51 ± 0.61	64.95 ± 0.40
JHMCS	4.1	32.04 ± 0.26	45.61 ± 0.43	59.88 ± 0.56	78.16 ± 0.54	100.79 ± 0.47
NDN	5.4	9.18 ± 0.33	12.92 ± 0.68	18.27 ± 0.69	25.64 ± 0.83	35.28 ± 0.56
NT	3.0	13.98 ± 0.26	19.57 ± 0.39	26.06 ± 0.64	34.00 ± 0.61	41.87 ± 0.44
AFT	3.3	15.05 ± 0.22	19.71 ± 0.37	25.79 ± 0.58	32.89 ± 0.85	40.53 ± 0.44

Table B-17: Mean ± One Standard Deviation HMy (in.-lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 6 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	4.80 ± 0.23	7.34 ± 0.31	10.88 ± 0.51	14.93 ± 0.70	20.20 ± 0.69
Lateral	4.0	3.89 ± 0.30	6.12 ± 0.35	9.17 ± 0.55	13.14 ± 0.69	17.60 ± 0.59
0 deg Pitch	4.0	7.89 ± 0.30	12.81 ± 0.38	18.69 ± 0.64	26.00 ± 0.74	34.29 ± 0.78
30 deg Pitch	4.0	12.60 ± 0.32	20.15 ± 0.32	29.02 ± 0.50	39.80 ± 0.65	52.41 ± 1.62
60 deg Pitch	4.0	16.55 ± 0.27	25.85 ± 0.37	36.72 ± 0.59	49.72 ± 0.70	64.14 ± 1.49
90 deg Pitch	4.0	16.45 ± 0.27	25.76 ± 0.40	36.32 ± 0.59	48.37 ± 0.82	62.51 ± 0.80
Lateral	4.5	3.20 ± 0.31	4.96 ± 0.33	7.78 ± 0.46	11.40 ± 0.72	15.62 ± 0.62
0 deg Pitch	4.5	9.60 ± 0.34	15.96 ± 0.44	23.59 ± 0.59	33.02 ± 0.70	44.51 ± 0.66
30 deg Pitch	4.5	19.89 ± 0.35	31.82 ± 0.51	46.03 ± 0.53	62.58 ± 0.67	82.06 ± 0.84
60 deg Pitch	4.5	26.34 ± 0.34	42.19 ± 0.52	60.74 ± 0.77	81.58 ± 1.02	104.36 ± 0.62
90 deg Pitch	4.5	27.94 ± 0.45	43.93 ± 0.50	62.14 ± 0.60	82.61 ± 0.71	104.63 ± 0.85
Lateral	5.0	1.40 ± 0.27	2.62 ± 0.30	4.65 ± 0.48	7.30 ± 0.61	10.95 ± 0.66
0 deg Pitch	5.0	11.71 ± 0.35	19.54 ± 0.44	29.10 ± 0.59	40.94 ± 0.60	55.41 ± 0.65
30 deg Pitch	5.0	27.02 ± 0.36	44.05 ± 0.40	64.29 ± 0.66	87.27 ± 0.91	113.04 ± 0.81
60 deg Pitch	5.0	37.49 ± 0.36	60.68 ± 0.46	86.71 ± 0.67	114.97 ± 1.10	146.06 ± 1.02
90 deg Pitch	5.0	39.64 ± 0.47	62.86 ± 0.56	88.34 ± 0.81	115.71 ± 1.17	144.71 ± 0.75
Lateral	5.5	1.88 ± 0.24	3.20 ± 0.33	5.61 ± 0.48	8.54 ± 0.58	12.48 ± 0.67
0 deg Pitch	5.5	13.88 ± 0.39	23.38 ± 0.44	35.42 ± 0.68	49.97 ± 0.91	69.47 ± 1.57
30 deg Pitch	5.5	34.93 ± 0.37	57.85 ± 0.42	83.94 ± 0.67	112.69 ± 0.77	144.61 ± 1.14
60 deg Pitch	5.5	49.73 ± 0.44	80.23 ± 0.56	114.08 ± 0.90	149.54 ± 1.09	187.37 ± 0.78
90 deg Pitch	5.5	51.56 ± 1.34	81.89 ± 0.55	114.50 ± 0.87	148.60 ± 1.25	183.86 ± 0.80
0.5 lb Right	4.5 Asymmetric	15.20 ± 0.33	25.04 ± 0.28	35.97 ± 0.53	48.62 ± 0.66	63.35 ± 0.63
1.5 lb Right	5.5 Asymmetric	15.86 ± 0.31	26.67 ± 0.31	38.45 ± 0.55	51.50 ± 0.67	66.22 ± 0.64
0.5 lb Left	4.5 Asymmetric	15.90 ± 0.36	25.64 ± 0.40	36.25 ± 0.54	48.20 ± 0.50	62.82 ± 1.18
1.5 lb Left	5.5 Asymmetric	16.78 ± 0.37	26.80 ± 0.37	38.35 ± 0.53	50.69 ± 0.56	64.54 ± 0.65
JHMCS	4.1	32.42 ± 0.35	46.81 ± 0.59	61.55 ± 0.50	78.43 ± 0.66	99.60 ± 0.68
NDN	5.4	9.36 ± 0.43	12.87 ± 0.67	17.98 ± 0.69	25.49 ± 0.84	34.45 ± 0.84
NT	3.0	14.88 ± 0.37	20.41 ± 0.42	26.62 ± 0.62	33.08 ± 0.60	40.33 ± 0.77
AFT	3.3	14.89 ± 0.39	19.37 ± 0.36	25.69 ± 0.72	32.67 ± 0.87	40.27 ± 0.43

Table B-18: HMy (in.-lb) (± One Standard Deviation) during +10 Gz SACM at +4, 6, 8, and 10 Gz Plateaus for the Tactical Lateral and Pitch Configurations and Helmet Systems

+8 Gz second plateau value represents the mean of the 2nd and 3rd repetitions. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
Control	3.5	5.05 ± 0.65	6.97 ± 0.65	7.89 ± 0.76	6.97 ± 0.83	10.84 ± 1.16	11.20 ± 1.28	14.87 ± 0.96
Lateral	4.0	4.15 ± 0.67	3.41 ± 0.65	6.56 ± 0.67	5.64 ± 0.74	9.19 ± 1.36	9.61 ± 1.29	12.77 ± 1.27
0 deg Pitch	4.0	8.18 ± 0.55	6.68 ± 0.57	13.09 ± 0.78	12.32 ± 1.04	18.63 ± 1.40	19.26 ± 1.33	26.04 ± 1.14
30 deg Pitch	4.0	13.18 ± 0.60	11.88 ± 0.64	20.90 ± 0.84	20.35 ± 0.94	29.76 ± 1.23	30.21 ± 1.22	40.40 ± 1.24
60 deg Pitch	4.0	16.56 ± 0.72	14.92 ± 0.64	25.87 ± 0.82	25.50 ± 1.14	36.63 ± 1.53	37.37 ± 1.45	49.53 ± 1.30
90 deg Pitch	4.0	17.15 ± 0.46	15.14 ± 0.76	26.31 ± 0.89	25.29 ± 1.23	36.54 ± 1.47	36.96 ± 1.38	48.64 ± 1.50
Lateral	4.5	3.38 ± 0.80	2.44 ± 0.64	5.41 ± 0.55	4.53 ± 0.63	7.70 ± 1.15	8.12 ± 1.42	10.97 ± 1.17
0 deg Pitch	4.5	10.06 ± 0.63	8.72 ± 0.87	16.33 ± 0.85	16.11 ± 1.15	24.00 ± 1.20	24.72 ± 1.28	33.45 ± 1.27
30 deg Pitch	4.5	20.35 ± 0.67	19.21 ± 0.91	32.77 ± 0.98	33.20 ± 1.22	46.97 ± 1.39	48.04 ± 1.15	63.83 ± 1.21
60 deg Pitch	4.5	26.86 ± 0.73	26.06 ± 0.74	43.05 ± 0.77	43.84 ± 1.51	61.40 ± 1.41	62.65 ± 1.41	82.10 ± 1.56
90 deg Pitch	4.5	28.40 ± 0.60	27.47 ± 0.84	44.64 ± 0.94	45.32 ± 1.21	62.85 ± 1.28	64.03 ± 1.60	83.30 ± 1.47
Lateral	5.0	1.77 ± 0.55	0.88 ± 0.63	2.96 ± 0.59	2.33 ± 0.95	4.65 ± 1.29	4.96 ± 1.18	7.17 ± 1.07
0 deg Pitch	5.0	12.25 ± 0.52	11.01 ± 0.84	20.00 ± 0.83	20.31 ± 1.00	29.68 ± 1.17	30.77 ± 1.37	41.63 ± 1.18
30 deg Pitch	5.0	27.67 ± 0.75	27.67 ± 0.67	45.23 ± 0.88	47.12 ± 1.11	65.45 ± 1.28	67.12 ± 1.32	88.55 ± 1.40
60 deg Pitch	5.0	38.56 ± 0.66	38.56 ± 0.93	62.22 ± 1.39	63.65 ± 1.16	88.03 ± 1.62	89.59 ± 1.56	116.17 ± 1.85
90 deg Pitch	5.0	40.25 ± 0.54	39.89 ± 0.80	63.93 ± 0.98	64.88 ± 1.42	89.21 ± 1.60	90.52 ± 1.61	116.51 ± 1.68
Lateral	5.5	2.11 ± 0.68	1.21 ± 0.59	3.67 ± 0.69	3.00 ± 0.97	5.57 ± 1.44	5.90 ± 1.28	8.21 ± 0.96
0 deg Pitch	5.5	14.57 ± 0.62	13.65 ± 0.64	24.08 ± 0.82	25.10 ± 1.03	35.88 ± 1.27	37.59 ± 1.44	50.79 ± 1.40
30 deg Pitch	5.5	35.85 ± 0.69	36.67 ± 0.88	58.98 ± 0.87	61.73 ± 1.13	85.05 ± 1.41	87.22 ± 1.50	114.19 ± 1.47
60 deg Pitch	5.5	50.53 ± 0.77	51.03 ± 0.88	81.42 ± 1.16	83.48 ± 1.18	114.86 ± 1.67	116.33 ± 1.51	150.14 ± 1.80
90 deg Pitch	5.5	52.95 ± 0.66	52.31 ± 0.89	83.53 ± 1.22	84.37 ± 2.19	115.57 ± 1.68	116.59 ± 1.88	149.37 ± 1.65

Table B-18 (Cont'd)

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
0.5 lb Right	4.5 Asymmetric	15.78 ± 0.45	14.72 ± 0.52	25.58 ± 0.93	25.18 ± 1.28	36.31 ± 1.10	36.73 ± 0.90	48.80 ± 1.22
1.5 lb Right	5.5 Asymmetric	17.16 ± 0.76	15.50 ± 0.55	27.36 ± 0.75	26.74 ± 0.74	38.73 ± 1.33	39.28 ± 1.22	52.03 ± 1.26
0.5 lb Left	4.5 Asymmetric	16.21 ± 0.77	14.37 ± 1.02	25.87 ± 0.67	25.01 ± 1.07	36.54 ± 1.22	36.95 ± 1.23	48.67 ± 1.23
1.5 lb Left	5.5 Asymmetric	16.59 ± 0.71	14.59 ± 0.84	26.81 ± 0.82	26.00 ± 1.47	38.03 ± 1.36	38.69 ± 1.43	51.06 ± 1.01
JHMCS	4.1	33.51 ± 0.56	33.36 ± 0.98	46.55 ± 1.09	47.92 ± 1.10	61.48 ± 1.24	62.73 ± 1.57	78.86 ± 1.39
NDN	5.4	9.51 ± 0.60	8.72 ± 0.66	13.53 ± 0.95	14.08 ± 0.99	19.17 ± 1.50	20.52 ± 1.39	26.49 ± 1.57
NT	3.0	15.18 ± 0.54	14.57 ± 1.00	20.31 ± 0.86	19.87 ± 0.97	26.02 ± 1.58	26.25 ± 1.62	31.88 ± 1.42
AFT	3.3	14.41 ± 0.53	14.07 ± 0.89	18.87 ± 0.81	18.80 ± 0.89	24.87 ± 1.57	24.87 ± 1.63	31.17 ± 1.28

Table B-19: Mean ± One Standard Deviation NMy (in.-lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 2 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	152.11 ± 1.51	267.46 ± 1.93	393.82 ± 2.56	526.99 ± 3.36	668.35 ± 2.34
Lateral	4.0	159.73 ± 1.46	280.18 ± 1.54	408.54 ± 2.55	545.81 ± 3.52	690.40 ± 2.14
0 deg Pitch	4.0	172.75 ± 1.02	300.86 ± 1.46	437.86 ± 2.10	582.75 ± 3.03	734.37 ± 1.98
30 deg Pitch	4.0	178.32 ± 1.00	309.62 ± 1.52	451.34 ± 2.26	600.81 ± 3.17	759.34 ± 2.27
60 deg Pitch	4.0	181.13 ± 1.08	313.90 ± 1.83	456.13 ± 2.70	608.79 ± 2.94	767.84 ± 2.01
90 deg Pitch	4.0	177.77 ± 1.26	309.54 ± 2.14	449.96 ± 2.58	599.32 ± 2.31	758.02 ± 2.07
Lateral	4.5	165.49 ± 1.27	289.95 ± 1.88	421.53 ± 2.77	561.36 ± 3.35	707.40 ± 2.42
0 deg Pitch	4.5	181.42 ± 1.04	316.08 ± 1.67	457.58 ± 2.34	609.12 ± 2.40	770.05 ± 1.85
30 deg Pitch	4.5	194.90 ± 1.08	335.34 ± 1.78	486.73 ± 2.12	649.69 ± 2.75	818.46 ± 2.16
60 deg Pitch	4.5	202.53 ± 1.28	347.05 ± 1.88	502.80 ± 2.79	666.79 ± 3.77	841.86 ± 2.64
90 deg Pitch	4.5	199.28 ± 1.06	343.88 ± 1.46	497.81 ± 2.59	661.77 ± 2.80	834.14 ± 2.22
Lateral	5.0	170.62 ± 1.23	296.88 ± 1.58	431.40 ± 3.31	574.62 ± 3.00	725.18 ± 2.34
0 deg Pitch	5.0	189.76 ± 0.98	331.58 ± 2.29	479.55 ± 2.29	638.72 ± 2.04	809.25 ± 1.70
30 deg Pitch	5.0	211.00 ± 0.98	363.18 ± 1.65	525.87 ± 2.17	696.37 ± 2.51	879.08 ± 2.07
60 deg Pitch	5.0	222.56 ± 1.06	381.15 ± 1.87	549.24 ± 2.37	725.71 ± 3.05	912.64 ± 2.28
90 deg Pitch	5.0	221.65 ± 1.10	378.10 ± 1.72	545.63 ± 2.74	721.91 ± 4.70	905.57 ± 2.41
Lateral	5.5	176.92 ± 1.20	307.67 ± 1.86	446.41 ± 3.18	593.44 ± 3.11	751.76 ± 2.13
0 deg Pitch	5.5	200.65 ± 1.14	345.09 ± 1.75	495.98 ± 2.19	668.90 ± 2.21	847.94 ± 2.10
30 deg Pitch	5.5	228.36 ± 1.19	391.02 ± 1.63	565.40 ± 2.46	750.06 ± 2.95	942.36 ± 2.38
60 deg Pitch	5.5	245.20 ± 1.20	416.83 ± 2.03	598.85 ± 3.06	787.97 ± 3.61	986.80 ± 2.25
90 deg Pitch	5.5	244.46 ± 1.14	413.99 ± 1.93	592.33 ± 3.14	777.78 ± 3.93	975.27 ± 2.09
0.5 lb Right	4.5 Asymmetric	193.20 ± 1.26	333.72 ± 2.13	481.52 ± 3.42	640.68 ± 3.46	803.94 ± 2.19
1.5 lb Right	5.5 Asymmetric	206.80 ± 1.61	354.08 ± 1.92	511.72 ± 3.36	673.07 ± 3.75	851.64 ± 2.07
0.5 lb Left	4.5 Asymmetric	191.95 ± 1.03	331.00 ± 1.71	479.40 ± 2.58	634.35 ± 2.31	799.53 ± 2.08
1.5 lb Left	5.5 Asymmetric	206.45 ± 1.41	352.70 ± 2.03	508.66 ± 2.58	671.64 ± 2.87	844.50 ± 2.07
JHMCS	4.1	203.22 ± 1.13	349.35 ± 2.04	500.29 ± 2.49	663.62 ± 2.43	840.62 ± 2.17
NDN	5.4	197.56 ± 1.36	335.86 ± 2.67	483.28 ± 2.67	641.68 ± 2.92	808.66 ± 2.23
NT	3.0	176.78 ± 1.26	305.25 ± 2.07	442.19 ± 3.08	586.41 ± 2.69	736.26 ± 2.00
AFT	3.3	177.39 ± 1.10	304.05 ± 1.74	438.15 ± 2.57	579.93 ± 3.75	726.81 ± 2.01

Table B-20: Mean ± One Standard Deviation NMy (in.-lb) for Tactical Lateral and Pitch Configurations and Helmet Systems at 6 G/sec Onset Rate

NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz	+6 Gz	+8 Gz	+10 Gz	+12 Gz
Control	3.5	154.30 ± 1.22	271.13 ± 1.75	397.87 ± 2.46	528.96 ± 2.94	670.42 ± 2.89
Lateral	4.0	159.91 ± 2.11	281.94 ± 1.99	410.36 ± 2.77	546.21 ± 3.22	690.59 ± 2.88
0 deg Pitch	4.0	172.46 ± 2.33	301.05 ± 1.71	437.53 ± 2.71	582.17 ± 3.01	733.72 ± 3.05
30 deg Pitch	4.0	180.41 ± 1.95	312.60 ± 1.63	453.77 ± 2.14	601.14 ± 2.69	753.64 ± 5.71
60 deg Pitch	4.0	182.36 ± 2.06	315.31 ± 1.71	457.04 ± 2.40	609.02 ± 2.78	768.96 ± 5.46
90 deg Pitch	4.0	179.68 ± 2.12	312.31 ± 1.73	452.75 ± 2.62	601.83 ± 3.50	758.55 ± 3.45
Lateral	4.5	166.24 ± 2.00	289.97 ± 1.82	421.90 ± 2.50	561.29 ± 3.34	709.47 ± 2.90
0 deg Pitch	4.5	182.09 ± 1.88	316.87 ± 1.87	459.39 ± 2.27	609.55 ± 2.61	769.12 ± 2.36
30 deg Pitch	4.5	195.98 ± 1.91	336.40 ± 1.97	488.01 ± 1.97	646.09 ± 2.77	816.22 ± 3.07
60 deg Pitch	4.5	203.56 ± 2.44	349.57 ± 2.08	506.11 ± 2.77	670.00 ± 3.52	841.79 ± 2.37
90 deg Pitch	4.5	201.97 ± 2.01	347.69 ± 1.89	501.22 ± 2.15	664.24 ± 2.84	834.37 ± 3.28
Lateral	5.0	171.68 ± 1.96	298.60 ± 1.71	433.27 ± 2.77	575.19 ± 3.25	725.30 ± 3.21
0 deg Pitch	5.0	192.64 ± 2.34	332.29 ± 1.80	481.30 ± 2.26	639.49 ± 2.21	805.35 ± 2.50
30 deg Pitch	5.0	212.53 ± 2.36	363.71 ± 1.74	525.71 ± 2.23	696.65 ± 3.07	878.56 ± 3.00
60 deg Pitch	5.0	225.07 ± 2.23	383.32 ± 1.74	551.60 ± 2.41	728.39 ± 3.97	917.51 ± 3.49
90 deg Pitch	5.0	224.23 ± 2.12	381.61 ± 2.20	548.13 ± 3.12	722.85 ± 4.62	905.97 ± 3.10
Lateral	5.5	177.68 ± 2.32	309.35 ± 1.91	448.34 ± 2.59	595.02 ± 3.04	749.35 ± 3.22
0 deg Pitch	5.5	201.29 ± 1.88	347.65 ± 1.74	504.32 ± 2.34	669.28 ± 3.06	851.44 ± 4.36
30 deg Pitch	5.5	230.07 ± 2.33	392.46 ± 1.61	565.53 ± 2.47	746.13 ± 2.75	940.46 ± 3.93
60 deg Pitch	5.5	248.26 ± 2.27	418.59 ± 2.16	601.45 ± 3.32	790.05 ± 3.94	990.56 ± 2.83
90 deg Pitch	5.5	244.58 ± 8.89	415.45 ± 1.98	595.42 ± 3.74	781.84 ± 4.88	977.62 ± 3.18
0.5 lb Right	4.5 Asymmetric	194.53 ± 3.36	333.91 ± 1.46	481.28 ± 2.50	637.96 ± 2.88	801.57 ± 2.67
1.5 lb Right	5.5 Asymmetric	207.74 ± 2.71	356.36 ± 2.20	512.06 ± 3.40	677.90 ± 3.87	850.57 ± 3.45
0.5 lb Left	4.5 Asymmetric	192.18 ± 2.98	332.06 ± 2.05	478.70 ± 2.52	632.50 ± 2.46	801.44 ± 4.93
1.5 lb Left	5.5 Asymmetric	207.23 ± 2.55	353.56 ± 2.00	508.61 ± 2.50	669.35 ± 2.67	847.21 ± 3.12
JHMCS	4.1	204.73 ± 1.46	352.24 ± 2.97	503.42 ± 2.12	664.79 ± 2.82	839.24 ± 2.82
NDN	5.4	198.17 ± 2.29	338.03 ± 2.71	485.40 ± 2.55	644.78 ± 2.98	807.91 ± 3.19
NT	3.0	177.91 ± 1.95	307.37 ± 2.37	443.84 ± 3.05	585.98 ± 2.78	733.54 ± 3.29
AFT	3.3	176.82 ± 2.27	302.47 ± 1.97	437.93 ± 3.57	577.73 ± 3.93	724.65 ± 2.07

Table B-21. NMy (in.-lb) (± One Standard Deviation) during +10 Gz SACM at +4, 6, 8, and 10 Gz Plateaus for the Tactical Lateral and Pitch Configurations and Helmet Systems

+8 Gz second plateau value represents the mean of the 2nd and 3rd repetitions. NDN: Crusader; NT: HGU 68/P; AFT: HGU 55/P.

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
Control	3.5	157.70 ± 2.96	162.22 ± 3.40	275.82 ± 3.22	283.65 ± 4.21	399.21 ± 6.22	404.05 ± 7.43	530.94 ± 5.47
Lateral	4.0	163.88 ± 3.15	168.16 ± 3.72	285.39 ± 3.28	293.06 ± 3.44	412.53 ± 8.05	417.14 ± 7.64	547.03 ± 7.23
0 deg Pitch	4.0	176.34 ± 2.12	181.50 ± 2.39	306.18 ± 2.93	313.98 ± 4.26	440.56 ± 6.68	445.64 ± 6.42	583.75 ± 5.52
30 deg Pitch	4.0	182.26 ± 2.21	187.48 ± 2.45	315.44 ± 2.92	323.37 ± 3.23	453.76 ± 5.86	458.57 ± 6.01	600.60 ± 6.06
60 deg Pitch	4.0	185.36 ± 2.62	191.66 ± 2.68	320.30 ± 2.91	329.79 ± 3.70	461.05 ± 7.09	466.61 ± 6.78	609.96 ± 6.26
90 deg Pitch	4.0	182.57 ± 1.69	188.81 ± 3.79	315.82 ± 3.09	325.08 ± 5.10	454.88 ± 7.67	460.31 ± 7.43	601.59 ± 8.20
Lateral	4.5	169.46 ± 3.86	174.16 ± 3.52	294.10 ± 2.63	302.21 ± 2.92	424.42 ± 6.60	429.24 ± 8.51	561.80 ± 6.72
0 deg Pitch	4.5	185.68 ± 2.17	191.99 ± 2.84	320.91 ± 2.73	330.26 ± 3.43	462.12 ± 5.11	467.29 ± 5.43	611.24 ± 5.54
30 deg Pitch	4.5	199.22 ± 2.29	205.27 ± 3.21	342.36 ± 3.25	351.58 ± 4.45	491.13 ± 5.96	496.47 ± 5.07	649.40 ± 5.45
60 deg Pitch	4.5	206.44 ± 2.34	213.48 ± 2.47	353.37 ± 2.20	363.65 ± 5.53	506.84 ± 5.76	512.80 ± 5.87	669.35 ± 6.86
90 deg Pitch	4.5	205.38 ± 1.90	213.22 ± 3.18	351.63 ± 2.82	362.05 ± 4.03	503.91 ± 5.54	510.03 ± 7.53	665.19 ± 7.18
Lateral	5.0	174.19 ± 2.77	178.61 ± 3.73	301.72 ± 3.00	309.69 ± 5.08	434.87 ± 8.17	439.06 ± 7.24	575.49 ± 6.44
0 deg Pitch	5.0	195.14 ± 1.83	202.25 ± 2.67	336.27 ± 2.87	346.49 ± 3.36	483.60 ± 4.51	489.41 ± 5.40	639.61 ± 4.87
30 deg Pitch	5.0	215.93 ± 2.23	223.70 ± 2.03	369.11 ± 2.50	380.19 ± 3.49	528.94 ± 4.89	535.09 ± 4.93	698.49 ± 5.53
60 deg Pitch	5.0	229.28 ± 1.86	237.57 ± 2.64	389.61 ± 5.11	399.98 ± 3.69	555.80 ± 6.83	561.93 ± 6.72	730.90 ± 7.94
90 deg Pitch	5.0	228.15 ± 1.62	236.00 ± 2.67	386.22 ± 2.98	396.93 ± 5.14	550.48 ± 7.22	557.32 ± 7.50	723.81 ± 8.32
Lateral	5.5	181.31 ± 3.35	185.93 ± 3.43	312.55 ± 3.58	320.35 ± 4.81	449.53 ± 8.82	454.01 ± 7.22	594.00 ± 6.07
0 deg Pitch	5.5	205.86 ± 1.84	213.61 ± 2.21	353.41 ± 2.46	364.90 ± 2.90	506.91 ± 4.60	514.43 ± 5.41	671.74 ± 5.04
30 deg Pitch	5.5	233.42 ± 2.02	242.46 ± 2.69	396.84 ± 2.73	409.86 ± 3.21	567.83 ± 5.11	574.98 ± 5.54	748.88 ± 5.44
60 deg Pitch	5.5	251.64 ± 1.77	260.62 ± 3.09	423.88 ± 4.24	435.34 ± 4.20	603.03 ± 6.95	608.81 ± 6.43	789.95 ± 7.97
90 deg Pitch	5.5	251.33 ± 1.96	259.11 ± 3.43	422.16 ± 4.02	432.33 ± 9.11	598.61 ± 8.11	604.57 ± 9.58	783.68 ± 8.21

Table B-21 (Cont'd)

Series	Total Weight (lb)	+4 Gz (1st Peak)	+4 Gz (2nd Peak)	+6 Gz (1st Peak)	+6 Gz (2nd Peak)	+8 Gz (1st Peak)	+8 Gz (2nd Peak)	+10 Gz
0.5 lb Right	4.5 Asymmetric	196.36 ± 1.88	202.21 ± 2.16	337.27 ± 3.86	345.80 ± 5.59	483.67 ± 5.32	488.86 ± 4.08	636.86 ± 6.06
1.5 lb Right	5.5 Asymmetric	211.25 ± 4.07	217.60 ± 2.90	360.35 ± 3.93	369.41 ± 3.67	515.62 ± 8.19	520.71 ± 7.74	679.17 ± 8.02
0.5 lb Left	4.5 Asymmetric	196.00 ± 3.09	202.09 ± 4.39	336.51 ± 2.73	345.50 ± 4.78	482.63 ± 6.30	487.71 ± 6.30	635.24 ± 6.73
1.5 lb Left	5.5 Asymmetric	210.95 ± 3.25	218.11 ± 4.04	359.43 ± 3.33	369.98 ± 8.17	514.29 ± 7.82	521.09 ± 8.10	677.43 ± 6.20
JHMCS	4.1	210.01 ± 2.13	219.22 ± 4.57	355.29 ± 4.61	368.17 ± 4.40	507.10 ± 5.99	514.15 ± 7.81	667.57 ± 6.86
NDN	5.4	202.23 ± 2.07	210.36 ± 2.53	343.28 ± 3.29	354.90 ± 3.53	489.48 ± 5.70	497.14 ± 5.34	645.49 ± 6.28
NT	3.0	181.91 ± 2.60	189.88 ± 5.31	311.87 ± 4.09	322.67 ± 4.77	446.56 ± 8.54	451.84 ± 8.97	587.03 ± 7.81
AFT	3.3	178.49 ± 2.45	187.32 ± 4.91	305.66 ± 3.34	317.67 ± 3.82	439.21 ± 8.58	444.04 ± 9.15	579.20 ± 5.69

Table B-22: Mean ± One Standard Deviation Head Acceleration (G) for Helicopter Lateral and Pitch Configurations and Helmet Systems at 0.5 G/sec Onset Rate

NH: HGU-84/P; NHV: HGU-84/P with ANVIS mockup; AH: HGU-56/P.

Series	Total Weight (lb)	HGx: +1.75 Gz	HGx: +4 Gz	HGy: +1.75 Gz	HGy: +4 Gz	HGz: +1.75 Gz	HGz: +4 Gz
Control	3.5	0.04 ± 0.01	0.24 ± 0.01	-0.11 ± 0.01	-0.20 ± 0.01	1.66 ± 0.00	3.80 ± 0.00
Lateral	4.0	0.06 ± 0.01	0.26 ± 0.01	-0.15 ± 0.00	-0.27 ± 0.01	1.65 ± 0.00	3.79 ± 0.00
0 deg Pitch	4.0	0.10 ± 0.01	0.36 ± 0.01	-0.19 ± 0.00	-0.35 ± 0.01	1.62 ± 0.00	3.76 ± 0.00
30 deg Pitch	4.0	0.11 ± 0.01	0.38 ± 0.01	-0.18 ± 0.01	-0.33 ± 0.01	1.60 ± 0.00	3.74 ± 0.00
60 deg Pitch	4.0	0.10 ± 0.01	0.38 ± 0.01	-0.14 ± 0.00	-0.24 ± 0.01	1.62 ± 0.00	3.75 ± 0.00
90 deg Pitch	4.0	0.08 ± 0.01	0.32 ± 0.01	-0.16 ± 0.00	-0.29 ± 0.01	1.63 ± 0.00	3.77 ± 0.00
Lateral	4.5	0.06 ± 0.01	0.27 ± 0.01	-0.16 ± 0.00	-0.29 ± 0.01	1.65 ± 0.00	3.79 ± 0.00
0 deg Pitch	4.5	0.10 ± 0.01	0.36 ± 0.01	-0.19 ± 0.00	-0.35 ± 0.01	1.63 ± 0.00	3.77 ± 0.00
30 deg Pitch	4.5	0.10 ± 0.01	0.39 ± 0.01	-0.17 ± 0.00	-0.34 ± 0.01	1.64 ± 0.00	3.79 ± 0.00
60 deg Pitch	4.5	0.11 ± 0.01	0.42 ± 0.01	-0,17 ± 0.00	-0.33 ± 0.01	1.61 ± 0.00	3.75 ± 0.00
90 deg Pitch	4.5	0.09 ± 0.01	0.38 ± 0.01	-0.17 ± 0.00	-0.31 ± 0.00	1.63 ± 0.00	3.76 ± 0.00
Lateral	5.0	0.06 ± 0.01	0.27 ± 0.01	-0.16 ± 0.00	-0.30 ± 0.00	1.64 ± 0.00	3.79 ± 0.00
0 deg Pitch	5.0	0.10 ± 0.01	0.37 ± 0.01	-0.19 ± 0.00	-0.36 ± 0.00	1.63 ± 0.00	3.75 ± 0.00
30 deg Pitch	5.0	0.11 ± 0.01	0.43 ± 0.01	-0.19 ± 0.00	-0.36 ± 0.01	1.63 ± 0.00	3.78 ± 0.00
60 deg Pitch	5.0	0.12 ± 0.01	0.47 ± 0.01	-0.18 ± 0.00	-0.34 ± 0.01	1.61 ± 0.00	3.73 ± 0.00
90 deg Pitch	5.0	0.11 ± 0.01	0.45 ± 0.01	-0.16 ± 0.00	-0.31 ± 0.01	1.62 ± 0.00	3.74 ± 0.00
Lateral	6.0	0.07 ± 0.01	0.28 ± 0.01	-0.17 ± 0.01	-0.30 ± 0.01	1.63 ± 0.00	3.77 ± 0.00
0 deg Pitch	6.0	0.11 ± 0.01	0.40 ± 0.01	-0.19 ± 0.00	-0.36 ± 0.01	1.62 ± 0.00	3.76 ± 0.00
30 deg Pitch	6.0	0.13 ± 0.01	0.52 ± 0.01	-0.20 ± 0.00	-0.37 ± 0.00	1.62 ± 0.00	3.74 ± 0.00
60 deg Pitch	6.0	0.15 ± 0.01	0.60 ± 0.01	-0.18 ± 0.00	-0.37 ± 0.01	1.60 ± 0.00	3.72 ± 0.00
90 deg Pitch	6.0	0.14 ± 0.01	0.58 ± 0.01	-0.13 ± 0.00	-0.23 ± 0.00	1.63 ± 0.00	3.72 ± 0.00
0.5 lb Right	4.5 Asymmetric	0.12 ± 0.01	0.42 ± 0.01	-0.10 ± 0.00	-0.15 ± 0.01	1.62 ± 0.00	3.75 ± 0.00
1.5 lb Right	5.5 Asymmetric	0.12 ± 0.01	0.41 ± 0.01	-0.17 ± 0.00	-0.27 ± 0.01	1.62 ± 0.00	3.76 ± 0.00
0.5 lb Left	4.5 Asymmetric	0.12 ± 0.01	0.40 ± 0.01	-0.19 ± 0.00	-0.33 ± 0.01	1.61 ± 0.00	3.74 ± 0.00
1.5 lb Left	5.5 Asymmetric	0.12 ± 0.01	0.39 ± 0.01	-0.21 ± 0.00	-0.36 ± 0.00	1.60 ± 0.00	3.75 ± 0.00
NH	3.2	0.12 ± 0.01	0.37 ± 0.01	-0.14 ± 0.00	-0.24 ± 0.01	1.62 ± 0.00	3.76 ± 0.00
NHV	5.1	0.14 ± 0.01	0.45 ± 0.01	-0.14 ± 0.00	-0.25 ± 0.00	1.62 ± 0.00	3.75 ± 0.00
AH	2.8	0.11 ± 0.01	0.36 ± 0.01	-0.12 ± 0.00	-0.21 ± 0.01	1.62 ± 0.00	3.76 ± 0.00

Table B-23: Mean ± One Standard Deviation Head and Neck Fxz (lb) for Helicopter Lateral and Pitch Configurations and Helmet Systems at 0.5 G/sec Onset Rate

Asymmetric series data represent resultant force including Fy (HFxyz (lb)). NH: HGU-84/P; NHV: HGU-84/P with ANVIS mockup; AH: HGU-56/P.

Series	Total Weight (lb)	HFxz: +1.75 Gz	HFxz: +4 Gz	NFxz: +1.75 Gz	NFxz: +4 Gz
Control	3.5	4.69 ± 0.11	33.27 ± 0.12	14.06 ± 0.13	59.69 ± 0.12
Lateral	4.0	5.43 ± 0.11	34.90 ± 0.12	15.76 ± 0.17	62.42 ± 0.15
0 deg Pitch	4.0	6.98 ± 0.11	35.64 ± 0.09	18.88 ± 0.15	65.57 ± 0.21
30 deg Pitch	4.0	6.54 ± 0.12	36.67 ± 0.11	18.84 ± 0.15	65.58 ± 0.17
60 deg Pitch	4.0	6.30 ± 0.08	36.51 ± 0.09	18.14 ± 0.12	64.92 ± 0.12
90 deg Pitch	4.0	6.05 ± 0.12	36.07 ± 0.11	18.58 ± 0.15	65.27 ± 0.14
Lateral	4.5	6.41 ± 0.11	36.79 ± 0.12	17.80 ± 0.13	65.44 ± 0.13
0 deg Pitch	4.5	7.62 ± 0.11	37.54 ± 0.12	19.78 ± 0.19	67.69 ± 0.16
30 deg Pitch	4.5	9.15 ± 0.11	40.03 ± 0.09	18.94 ± 0.15	66.95 ± 0.16
60 deg Pitch	4.5	7.81 ± 0.10	39.84 ± 0.06	18.95 ± 0.16	67.11 ± 0.09
90 deg Pitch	4.5	7.13 ± 0.11	39.06 ± 0.09	19.88 ± 0.17	67.78 ± 0.14
Lateral	5.0	7.03 ± 0.12	38.65 ± 0.12	19.11 ± 0.15	68.11 ± 0.15
0 deg Pitch	5.0	8.37 ± 0.12	39.41 ± 0.11	22.17 ± 0.18	69.52 ± 0.18
30 deg Pitch	5.0	9.76 ± 0.10	42.16 ± 0.11	20.03 ± 0.18	69.13 ± 0.17
60 deg Pitch	5.0	9.15 ± 0.11	42.63 ± 0.09	20.26 ± 0.17	69.16 ± 0.14
90 deg Pitch	5.0	8.73 ± 0.11	42.11 ± 0.13	19.68 ± 0.16	68.69 ± 0.16
Lateral	6.0	8.83 ± 0.13	42.69 ± 0.10	21.85 ± 0.17	72.71 ± 0.15
0 deg Pitch	6.0	10.68 ± 0.11	44.36 ± 0.11	23.06 ± 0.22	73.82 ± 0.14
30 deg Pitch	6.0	11.40 ± 0.10	46.70 ± 0.11	22.34 ± 0.20	73.31 ± 0.17
60 deg Pitch	6.0	11.97 ± 0.11	48.71 ± 0.08	22.37 ± 0.16	73.91 ± 0.10
90 deg Pitch	6.0	11.68 ± 0.12	48.26 ± 0.14	21.98 ± 0.14	73.00 ± 0.16
0.5 lb Right	4.5 Asymmetric	9.74 ± 0.14	39.83 ± 0.13	20.70 ± 0.16	68.64 ± 0.18
1.5 lb Right	5.5 Asymmetric	11.60 ± 0.16	44.29 ± 0.09	23.36 ± 0.20	73.42 ± 0.18
0.5 lb Left	4.5 Asymmetric	10.49 ± 0.11	39.97 ± 0.10	21.30 ± 0.13	69.00 ± 0.17
1.5 lb Left	5.5 Asymmetric	12.69 ± 0.14	44.42 ± 0.11	23.51 ± 0.19	73.67 ± 0.14
NH	3.2	5.58 ± 0.08	30.11 ± 0.08	16.18 ± 0.16	61.12 ± 0.18
NHV	5.1	7.72 ± 0.09	39.82 ± 0.12	19.57 ± 0.17	69.03 ± 0.16
AH	2.8	3.64 ± 0.10	30.27 ± 0.09	16.02 ± 0.15	59.76 ± 0.18

Table B-24: Mean ± One Standard Deviation Head and Neck My (in.-lb) for Helicopter Lateral and Pitch Configurations and Helmet Systems at 0.5 G/sec Onset Rate

NH: HGU-84/P; NHV: HGU-84/P with ANVIS mockup; AH: HGU-56/P.

Series	Total Weight (lb)	HMy: +1.75 Gz	HMy: +4 Gz	NMy: +1.75 Gz	NMy: +4 Gz
Control	3.5	2.98 ± 0.23	4.83 ± 0.26	32.17 ± 1.32	152.11 ± 1.28
Lateral	4.0	2.01 ± 0.21	3.99 ± 0.23	33.70 ± 1.12	159.57 ± 1.13
0 deg Pitch	4.0	4.24 ± 0.16	8.52 ± 0.18	38.80 ± 1.18	172.51 ± 0.94
30 deg Pitch	4.0	6.53 ± 0.24	13.26 ± 0.22	41.55 ± 1.36	178.52 ± 0.86
60 deg Pitch	4.0	8.37 ± 0.15	17.19 ± 0.26	43.18 ± 0.83	181.15 ± 1.00
90 deg Pitch	4.0	7.98 ± 0.46	17.09 ± 0.25	41.37 ± 1.44	177.65 ± 0.91
Lateral	4.5	1.57 ± 0.24	3.23 ± 0.28	36.51 ± 1.16	165.80 ± 1.30
0 deg Pitch	4.5	4.86 ± 0.24	10.36 ± 0.25	41.86 ± 1.04	181.55 ± 0.99
30 deg Pitch	4.5	9.05 ± 0.19	20.38 ± 0.30	47.87 ± 0.97	194.77 ± 1.03
60 deg Pitch	4.5	11.89 ± 0.21	26.76 ± 0.29	50.86 ± 1.04	202.42 ± 1.04
90 deg Pitch	4.5	12.63 ± 0.44	27.68 ± 0.33	50.65 ± 1.03	199.46 ± 1.04
Lateral	5.0	0.90 ± 0.19	1.59 ± 0.23	38.03 ± 0.97	170.69 ± 1.17
0 deg Pitch	5.0	5.63 ± 0.31	12.22 ± 0.25	46.64 ± 1.44	189.85 ± 1.01
30 deg Pitch	5.0	11.82 ± 0.15	27.59 ± 0.29	54.48 ± 0.76	211.09 ± 1.00
60 deg Pitch	5.0	16.14 ± 0.26	37.59 ± 0.33	60.03 ± 0.95	222.48 ± 1.12
90 deg Pitch	5.0	17.48 ± 0.25	39.91 ± 0.46	59.68 ± 0.90	221.50 ± 1.18
Lateral	6.0	2.60 ± 0.34	5.09 ± 0.21	46.40 ± 1.93	187.56 ± 1.16
0 deg Pitch	6.0	7.28 ± 0.22	16.78 ± 0.35	55.76 ± 1.03	211.32 ± 1.22
30 deg Pitch	6.0	17.84 ± 0.23	43.18 ± 0.29	68.82 ± 0.85	245.29 ± 1.08
60 deg Pitch	6.0	25.31 ± 0.24	61.98 ± 0.39	78.68 ± 0.88	269.23 ± 1.18
90 deg Pitch	6.0	27.67 ± 0.40	64.16 ± 0.56	80.95 ± 1.03	268.36 ± 1.35
0.5 lb Right	4.5 Asymmetric	7.47 ± 0.35	16.40 ± 0.36	48.63 ± 1.80	193.64 ± 1.97
1.5 lb Right	5.5 Asymmetric	7.51 ± 0.42	17.36 ± 0.30	53.97 ± 2.16	206.93 ± 1.89
0.5 lb Left	4.5 Asymmetric	7.42 ± 0.18	16.65 ± 0.22	46.95 ± 1.21	191.46 ± 0.96
1.5 lb Left	5.5 Asymmetric	7.17 ± 0.51	17.81 ± 0.27	53.10 ± 2.09	206.93 ± 1.15
NH	3.2	7.95 ± 0.23	5.98 ± 0.25	31.68 ± 1.23	153.04 ± 1.21
NHV	5.1	17.22 ± 0.31	25.38 ± 0.36	59.29 ± 1.66	207.98 ± 1.44
AH	2.8	-1.47 ± 0.30	0.29 ± 0.27	28.47 ± 1.78	152.30 ± 1.38

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